#### **NYSG Progress Report Instructions & Required Format**

Please include the following information for your project. The text of this report should be about 3-4 pages long and be composed for an audience of your peers. Other formats, or reports with incomplete sections, will not be accepted. The expectation is that information or material will be provided under each section.

REPORT WRITTEN BY:	CAITLIN YOUNG	DATE:	1-3-13	

#### A. PROJECT NUMBER AND TITLE:

R-CTP-44-NYCT 'Sources and Fate of Nitrogen in North Shore Embayments'

#### **B. PROJECT PERSONNEL:**

Dr. Gilbert Hanson, Principal Investigator
Dr. Teng-Fong Wong, Co- Principal Investigator
Caitlin Young, NYSG Scholar
Neal Stark, Senior Research Support Specialist
Josephine Durand, Graduate Research Assistant
Ron Paulsen, Suffolk County Department of Health Services Personnel
Jonathan Wanlass, Suffolk County Department of Health Services Personnel

#### C. TIME INTERVAL:

6-15-12 to 12-15-12

#### **D. PRELIMINARY RESULTS:**

Note- Pictorial presents data grouped together by site location and sampling date. For instance, all resistivity transects, porewater nutrient transects and seepage meter results for port Jefferson Harbor at Belle Terre are presented in figures 10,11,12. This was done for easy comparison of results by site/time. Therefore figures listed in progress narrative are not necessarily consecutive.

- Objective 1: Conduct SuperSting resistivity transects to determine the amount of groundwater entering port Jefferson Harbor.
- **Progress 1:** Areas of SuperSting resistivity data collection gathered in May and July 2012 are shown in figure 1. Resistivity transects were taken at the same locations as piezometer wells (May, fig. 1 red) and cluster wells (July, fig 1 yellow). Results show two scenarios define the subterranean estuary in PJH, shown in figures 5,7,11. Areas with high inland relief exhibit fresh groundwater seeps from the beach face that are disconnected to coastal tidal fluctuations, figure 5(May) and figure 8 (July). These areas are found to have no upper saline plume and coincide with maximum nitrate concentrations found during trident survey (see RCTP44NYCT Progress Report July 2012, figure 2). The second scenario is representative of ~80% of the harbor's eastern coastline, figure 11. In these areas inland topography is lower, which allows

the development of an upper saline plume. This plume is underlain by fresh groundwater that discharges at or just below low tide.

- **Objective 3:** Identify any variations in SGD in the spring and fall periods following periods of highest and lowest recharge to the groundwater and how these impact overall nitrogen loading to the harbors.
- **Objective 4:** Use piezometers to collect samples in the subterranean estuary. Transects will be 8-10 meters long, consisting of 10-15 sampling points with depth into the sediment ranging from 0-2 meters Use these samples to define zones of salinity. Collect sub-bottom pore water samples to characterize the *in situ* nitrogen concentrations from the seawater sediment interface to a maximum depth of 60cm.
- Progress 3/Progress 4: Piezometer and cluster well transects in Port Jefferson Harbor were sampled in both the spring, summer and and fall of 2012. Spring samples were taken 4-18-12 to 5-17-11 at Centennial Beach in Port Jefferson and in Setauket harbor. Cluster wells installed 6-11-12 to 6-12-12 at two sites: Centennial Beach (4 wells) and Belle Terre (5 wells). These wells (9 total) were sampled during summer (7-10-12 to 7-11-12) and fall (10-23-12 to 10-25-12). Locations of all sampling points shown in figure 1. Additional sampling was done in Setauket harbor, adjacent to Port Jefferson Harbor, locations shown in figure 2.
- Progress 3: Submarine groundwater discharge rate measurements were taken using and Ultrasonic Seepage meter (figures 4 and 10) and manual seepage meters (figures 9 and 12). In port Jefferson Harbor at Centennial beach field ultrasonic seepage meter results from May 2012 show SGD rates ranging 70-100cm/d. At the same site in July 2012 manual seepage meter results show SGD rate of 79cm/d. In Port Jefferson Harbor at Belle Terre Ultrasonic seepage meter measurements taken offshore in July 2012 show SGD rates of ~3cm/d. Manual seepage meter rates recorded at the same time but from 1m below the low tide line indicate SGD rates of 18cm/d. The difference in rates at this site is likely due to seepage meter placement, which indicates the bulk of discharge occurs at or just below the low tide line and discharge attenuates rapidly offshore.
- Progress 4: Samples were collected at the locations (figures 1, 2) and times described in Progress 3(above).
   Sample resolution from piezometers ranged 2cm-100cm, depending on water porewater production at discrete depths, to a maximum sampling depth of 10.8m. Cluster wells are screened using 2cm screens at 1m intervals to a maximum depth of 15.2m.
- **Objective 5**: Analyze all samples for nitrogen species, phosphate and major electron donors. Use this information to determine the major nitrate attenuation/generation processes.

- Progress 5: Samples from October collection time are currently being analyzed. Salinity, dissolved oxygen, nitrate and ammonium data from the spring and summer period is shown in figures 3 (Setauket Harbor, May), figure 3 (Centennial Beach, May), figure 7 (Centennial Beach, July), figure 10 (Belle Terre, July). All samples are currently being analyzed for N2/Ar and <sup>15</sup>N-NO<sub>3</sub> to determine extent of denitrification.
  - O Setauket Harbor- May 2012 (figure 3): Five piezometer wells were sampled across the mouth of the harbor (figure 2) to a maximum depth of 10m. A very thin layer of salt water exists in the top 6cm of the harbor and at the harbor edges, indicating the harbor is primarily fed by seeping groundwater. The occurrence of high salinity samples at the harbor edges coincides with depletion of dissolved oxygen (fig. 3B), which indicates recirculated seawater causes reducing conditions in this area. Nitrate concentrations (fig. 3C) range from 0 at harbor edges to a maximum of 641μML<sup>-1</sup> at a depth of 142cm in the eastern side of the harbor. Samples in freshwater on the western side of the harbor contain nitrate concentrations <200 μML<sup>-1</sup>. Ammonium concentrations are low throughout the section (fig3D), reaching a maximum of 226.8μML<sup>-1</sup> in the shallow east edge of the harbor at a depth of 20cm, which coincides with maximum salinity and minimum dissolved oxygen concentrations.
  - O Port Jefferson Harbor- Centennial Beach- May 2012 (figure 4): Salinity (fig 4A) is less than 5ppt throughout the 20m sampling transect except for one sampling point where 21ppt salinity was recorded at a depth of 12cm in at the high tide mark. This is likely due to seawater infiltrated during high tide stage. Dissolved oxygen (fig 4B) ranges from 3mgL<sup>-1</sup> to 6mgL<sup>-1</sup> in all samples. The shape of high (5-6 mgL<sup>-1</sup>, fig. 4B in red) porewater samples indicates the strongest plume of groundwater discharges just below the low tide mark. Nitrate concentrations (fig. 4C) reach a maximum concentration of 540 μML<sup>-1</sup> at a depth of 106cm in the high tide mark piezometer. Values appear to undergo dilution during discharge; further analysis is underway to model dilution factors in these samples. Ammonium concentrations range between 0- 50μML<sup>-1</sup> for most of the cross section, except one sample that measured 113.6 μML<sup>-1</sup>, the same sample with 21ppt salinity.
  - o Port Jefferson Harbor- Centennial Beach- July 2012 (figure 7): This transect was used to determine temporal differences in SGD and associated nutrient discharge in an area of high SGD rate in Port Jefferson Harbor. Note sample resolution is lower in this transect as cluster wells are screened at intervals of ~2m, but samples were taken from further offshore (note differences in x axis in figure 7 and 4). Salinity (fig. 7A) is again very low, less than 5ppt for the entire sampling area. Dissolved oxygen concentrations are slightly higher (fig. 7B), with maximum of 7.8mgL<sup>-1</sup> but

areas of high and low dissolved oxygen are similar to those noted during May sampling. Nitrate concentrations are highest in upgraident (high tide mark) wells with clear attenuation in offshore samples (fig. 7C). Finally, ammonium concentrations are again low ranging  $0-50\mu ML^{-1}$  greater than 95% of samples. Maximum ammonium concentration of 135.6  $\mu ML^{-1}$  is seen in samples taken from depths greater than 920cm in an offshore well (fig. 7D). This is likely due to interception with the underlying salt wedge at this position.

- Port Jefferson Harbor- Belle Terre- July 2012 (Figure 10): Samples were taken from a Belle Terre field site (see figure 1) in July and October of 2012. Data from July sampling is shown in figure 10. Salinity ranges 23-25ppt in the shallow portion of the cross section (fig. 10A), which is close to overlying water values of ~28.5-29.7. At depths greater than 300cm in high tide and intertidal wells salinity drops to less than 5ppt, indicating fresh groundwater at these depths. Offshore wells, which have a lower sampling resolution due to difficulties in pumping porewater from muddy sediment, contain salt water in excess of 15ppt until depths of 10m. At depths greater than 10m water is fresh, which indicates the presence of a thick mud/silt sediment sequence overlying the fresh water prevents vertical movement of groundwater into the Harbor offshore. Dissolved oxygen (fig. 10B) is highest in areas of low salinity, particularly from intertidal samples deeper than 700cm. Nitrate concentrations are low throughout the section, with maximum value of 254.1µML<sup>-1</sup> at a depth of 182cm. Ammonium concentrations (fig. 10D) are highest in offshore samples, with a maximum values ranging 83.1  $\mu$ ML<sup>-1</sup> 87.4  $\mu$ ML<sup>-1</sup> in samples taken from depths ranging 450-910cm. These finding support the presence of a thick mud/silt sequence that prevents significant SGD offshore at this site. Further, we found SGD rates offshore of ~3cm/d as compared to SGD rates near low tide of 18cm/d.
- Objective 7: Apply study results to existing nitrogen loading models and distribute study results via publication and at local and national conferences.
- Progress 7: Data from this time period was presented at two conferences: International Association of
  Hydrogeologists in September 2012 and American Geophysical Union Fall Meeting in December 2012.
   Please see attached .pdf's for details presented.

#### E. BUDGET:

<b>Expenditure Category</b>	Budget	Expenditure	Encumbrance	Available Balance
Salaries and Wages Regular	32,083.00	50,663.36	4,653.85	-23,234.21
Total Salaries and Wages-				
-	32,083.00	50,663.36	4,653.85	-23,234.21
Fringe Benefits Regular	13,228.00	21,022.66	2,001.14	-9,795.80
Total Fringe Benefits	13,228.00	21,022.66	2,001.14	-9,795.80
Supplies	17,226.00	13,553.38	490.35	3,182.27
Travel	6,280.00	2,520.02	124.60	3,635.38
Subawards	46,000.00	0.00	0.00	46,000.00
Postage and Publishing	0.00	866.65	0.00	-866.65
General Services	0.00	1,560.83	0.00	-1,560.83
Campus Services Recharges	0.00	1,368.00	0.00	-1,368.00
Total Other	69,506.00	19,868.88	614.95	49,022.17
TOTAL Direct Costs	114,817.00	91,554.90	7,269.94	15,992.16
F and A Costs	31,663.00	30,899.78	763.22	0.00
Total F and A Costs	31,663.00	30,899.78	763.22	0.00
TOTAL Indirect Costs	31,663.00	30,899.78	763.22	0.00
TOTAL	146,480.00	122,454.68	8,033.16	15,992.1

#### **OUTSTANDING BUDGET ITEMS**

The following expenditures are currently being processed, and will not be paid until analyses are complete. As all samples were submitted during this recording period we are including them here, but they are not reflected in the total remaining award amount.

	Amount	Reason
Supplier	Owed	
		Cation analysis of samples
Cornell University Nutrient Analysis		from Stony Brook Harbor
Laboratory	\$952.00	
		Nitrate isotope analysis of samples from
		Stony Brook Harbor
University Of Arizona- Stable Isotope Facility	\$1,662.50	
		DOC/DOC and solid C/N analyses of
Stony Brook University- Nutrient Analyses		samples from Port Jefferson Harbor
lab	\$2,360.20	
		Trace metal analysis of porewater
		samples from Stony Brook Harbor and
Stony Brook University- ICP-MS	\$1,200.00	Port Jefferson Harbor

Total	\$6,174.70	

#### F. INTERACTIONS:

Suffolk County Department Health Services- We would like to stress that this project would not be possible without the gracious assistance of SCDHS. They have provided the following services without charge and are consistently available to provide extra manpower for field portions of this project.

- Boat and crew for collection of offshore cluster well samples in July and October 2012
- Use of Ultrasonic seepage meters in May, July and October of 2012
- Post processing of Ultrasonic seepage meter data taken during the above time periods

#### **G. Presentations and Publications:**

#### **Presentations:**

<u>Young, C. R.,</u> and G.N. Hanson. 2012 'Fate of nitrogen during Oxic Submarine Groundwater Discharge into Stony Brook Harbor, New York'. International Association of Hydrogeologists. Niagara Falls, CN September 21. Talk

Young, C. R., J.M. Durand, A.Rajendra and G.N. Hanson 2012. 'Nutrient Dynamics in a Subterranean Estuary over two Spring Neap tidal cycles'. American Geophysical Union. San Francisco, CA, December 7 poster

<u>Durand, J.M.</u>, C.R. Young, G.N.Hanson and T.F. Wong. 2012 'Submarine groundwater discharge (SGD) in Stony Brook Harbor, NY' American Geophysical Union. San Francisco, CA, December 7 poster

#### H. Scholar(s) & Student(s) & Volunteers (if applicable):

- **H1.** Scholar(s): Caitlin Young- NYSG Scholar. Anticipated graduation date August 2013.
- **H2. Student(s):** Josephine Durand- Research Assistant. Assisted with resistivity data collection and processing. Responsible for resistivity data inversion. She is not financially supported on this project.
- WOLUNTEERS: Tsou ShuHsing, an undergraduate student in Marine Sciences assisted on the project from July-September 2012. She collected manual seepage meter measurements in Port Jefferson Harbor and provided assistance with chemical analyses. She is not financially supported on this project.

#### **I. Pictorial:** See separate file.

R-CTP-44-NYCT 'Sources and Fate of Nitrogen in North Shore Embayments' Pictorial

Note- Pictorial presents data grouped together by site location and sampling date. For instance, all resistivity transects, porewater nutrient transects and seepage meter results for port Jefferson Harbor at Belle Terre are presented in figures 10,11,12. This was done for easy comparison of results by site/time. Therefore figures listed in progress narrative are not necessarily consecutive.



Figure 1 Port Jefferson Harbor sampling points. Red dots indicate location of piezometer sampling done at Centennial Beach in May 2012. Yellow dots indicate locations of cluster wells in both Centennial Beach and Belle Terre which were, sampled in July 2012 and October 2012.



Figure 2 Setauket Harbor sampling locations. Samples were taken in April-May 2012.

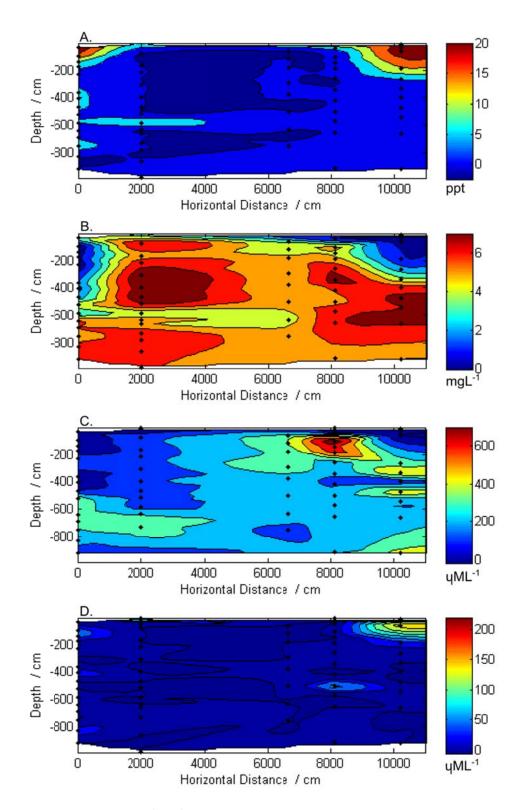


Figure 3 Analyte profiles from Setauket Harbor, data taken in April 2012. Salinity (A), dissolved oxygen (B), nitrate (C), and ammonium (D). Horizontal distance runs from west (0) to east (10000) across the harbor mouth (see figure 2).

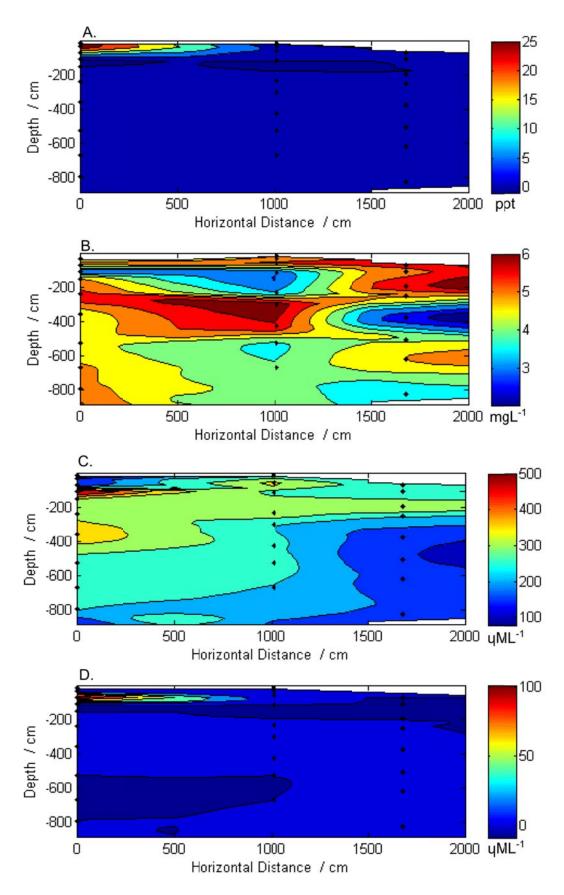


Figure 4 Analyte profiles in Port Jefferson Harbor at Centennial Beach, May 2012 (figure 1, red). Salinity (A), dissolved oxygen (B), nitrate (C), and ammonium (D). Horizontal distance runs from the high tide mark to 6 meters beyond the low tide mark, see figure 2.

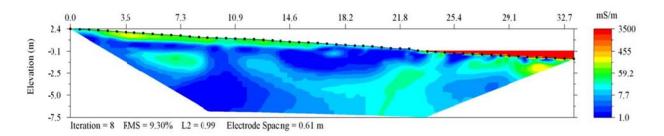


Figure 5 Conductivity profile from Port Jefferson Harbor at Centennial beach, May 2012. Very low values of conductivity (<50 mS/m) are observed on the whole transect. This indicates the pore water is saturated with water of very low salinity. Slightly higher values are visible close to the high tide mark (x = 3.6 m) and also under the low tide mark (x > 27 m and -0.1 < z < -2.5 m). In these locations, it seems like the freshwater is partially mixed with infiltrating seawater of higher conductivity (3500 mS/m).

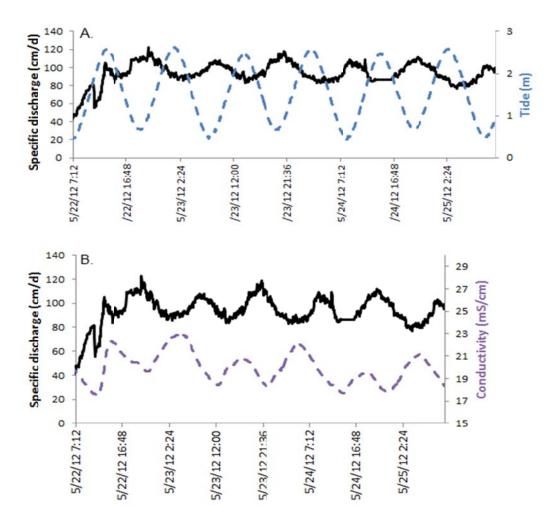


Figure 6 Ultrasonic seepage meter measurements from Port Jefferson Harbor at Centennial Beach, May 2012. Funnel A (top) was placed at the low tide mark, Funnel 2 (B) was placed 2 meters below the low tide mark. A clear anti-tide correlation is observed in both funnels, with maximum discharge occurring at low tide. Conductivity values, indicating salinity variation, correlate with tide, with maximum conductivity in seepage water observed at high tide. Average salinity during the 3 day sampling period is 16ppt and 22ppt for funnels A and B respectively. Average discharge rate is 100cm/d and 70cm/d for funnels A and B respectively.

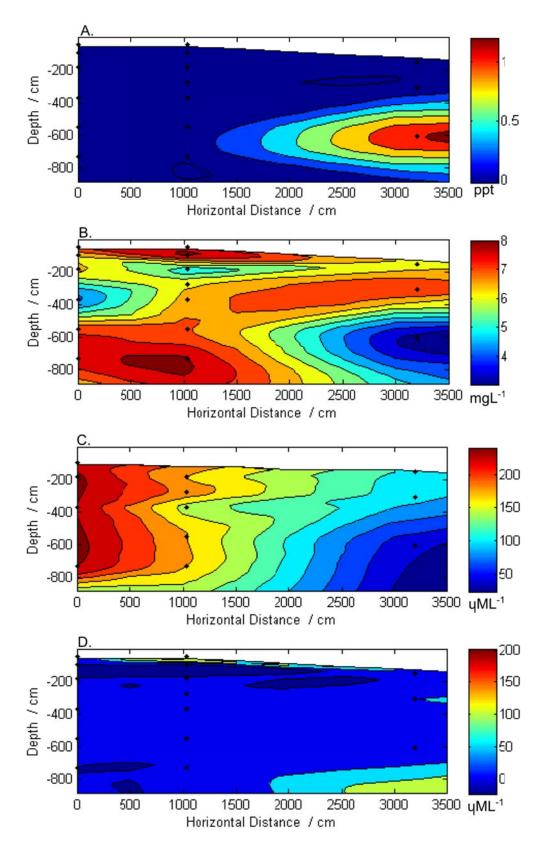


Figure 7 Analyte profiles in Port Jefferson Harbor at Centennial Beach, July 2012. Shown from top: salinity (A), dissolved oxygen (B), nitrate (C), and ammonium (D). Samples were taken from cluster wells installed in June 2012. Note difference in horizontal scales between May and July data.

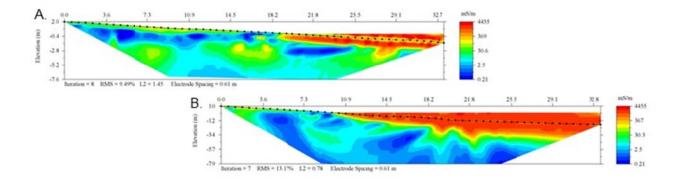


Figure 8 SuperSting conductivity survey at Centennial Beach on July 11<sup>th</sup> 2012. PJH-1B was acquired along the PJH-1A line but with a translation of 13 m seaward. This double transect clearly shows freshwater concentrations in the subsurface landward of the low tide line (A, x=23.2m). Conductivity measurements agree well with cluster well salinity profiles taken in July (fig 4A), where salinity reaches a maximum of 1ppt at a depth of 524cm beneath the surface. As offshore cluster well sampling depths were limited (due to mud/clay layers) the salinization of sediments at depths from 0-2m is not observed in figure 4A, but is seen in 5B.

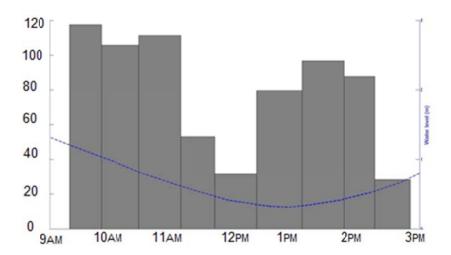


Figure 9 Manual seepage meter measurements in Port Jefferson Harbor at Centennial Beach, July 10, 2012. Water level above the meter is shown for reference. Average discharge rate is 79cm/d. This agrees well with data taken from May 2012, where discharge rate ranged between 70-100cm/d.

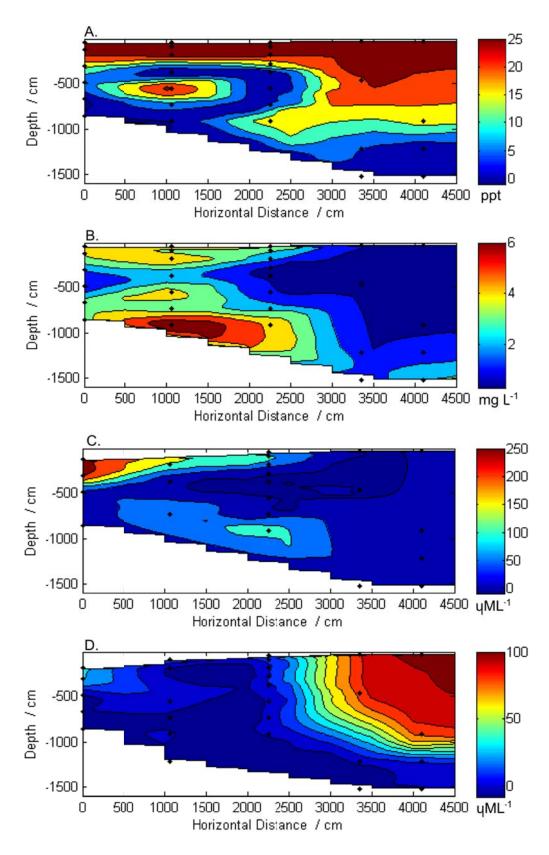


Figure 10 Analyte profiles in Port Jefferson Harbor at Belle Terre Beach, July 2012. Shown from top: salinity (A), dissolved oxygen (B), nitrate (C), and ammonium (D). Samples were taken from cluster wells installed in June 2012. White areas indicate no data. Two offshore wells (at x=3300cm and x=4200cm) have fewer sampling points due to layers of mud/clay that did not produce water. To allow for complete profiles, grab samples were taken at sediment water interface during sampling, but at x=4200cm we cautiously interpret fully saline porewater, as there is a ~10m vertical gap in sampling points.

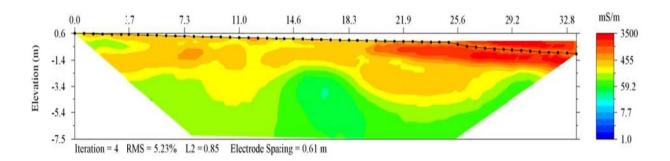


Figure 11 Conductivity section in Port Jefferson Harbor at Belle Terre. This section is very different from the one observed at Centennial beach. Here, the profile is much less homogeneous. Very high conductivity values close to seawater values are observed close to the shore (x>20 m, 0<z<-1.4 m). This shows a more infiltration of sweater in the top part of the sediments. Intermediate to high values are found down to 4m depth on the whole section, indicating significant mixing between fresh and seawater. Below 5 m depth, the resistivity values are lower and reveal a more diffuse mixing with fresh groundwater.

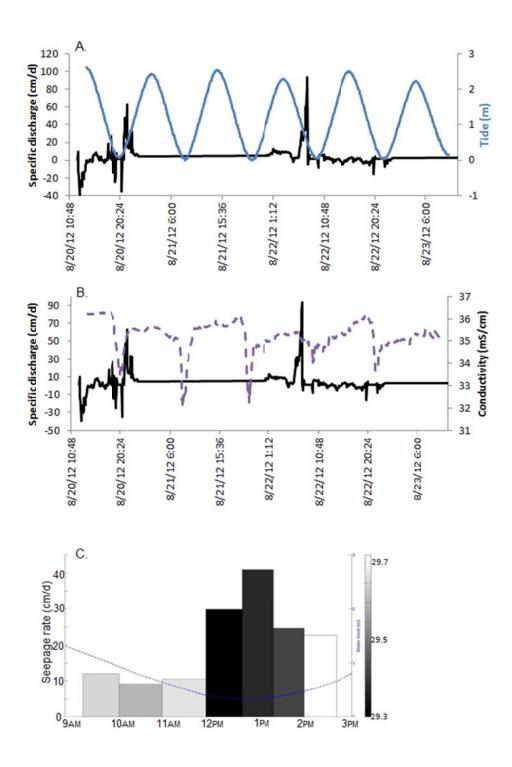


Figure 12 Seepage meter measurements from Port Jefferson Harbor at Belle Terre, taken July 2012. Ultrasonic seepage meter measurements from funnel A (top) and funnel B (middle) placed 2m and 4m below low tide respectively. Seepage rates show no tidal correlation, but conductivity of seepage water (B) shows a positive correlation with tidal stage (A). Discharge rate is ~3cm/d for both meters. Manual seepage meter (C) was placed less than 1m below low tide line. In manual measurements discharge is inversely correlated with tidal stage (shown in blue). Times of maximum discharge exhibit slightly lower salinities, indicating maximum time of fresh groundwater input. Average discharge rate is 18cm/d, significantly higher than values recorded further offshore. This is likely due to placement of seepage meters, and indicates that maximum seepage occurs within 1m of the low tide point, then fresh discharge rapidly attenuates offshore.

# Fate of nitrogen during Oxic Submarine Groundwater Discharge into Stony Brook Harbor, New York

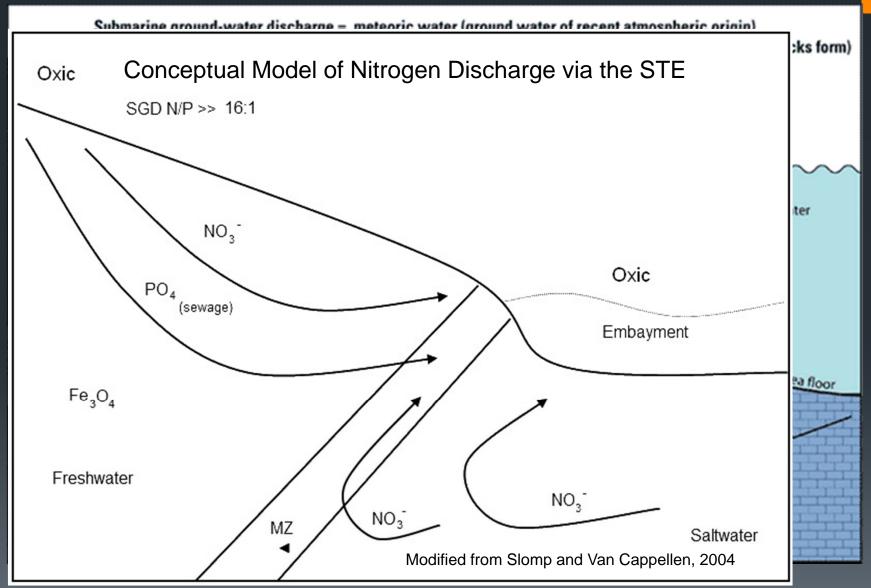
Caitlin Young, Josephine Durand, Gilbert Hanson, Teng-Fong Wong
Stony Brook University, Geosciences Department







# Submarine Groundwater Discharge and Subterranean Estuary



#### Eutrophication of Long Island Sound via Nitrogen rich SGD?

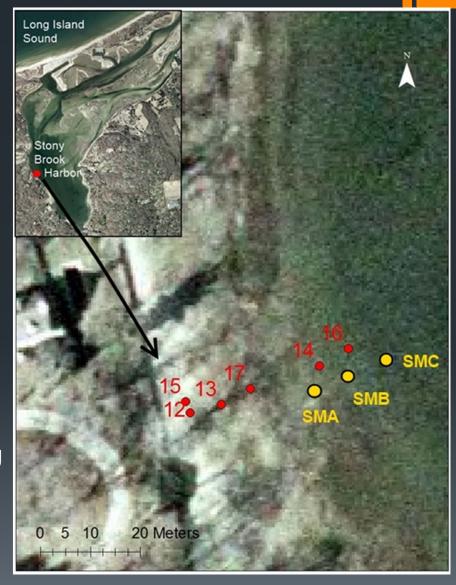


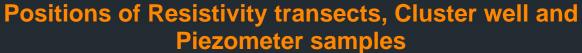
70% of Suffolk County residences have on site wastewater systems

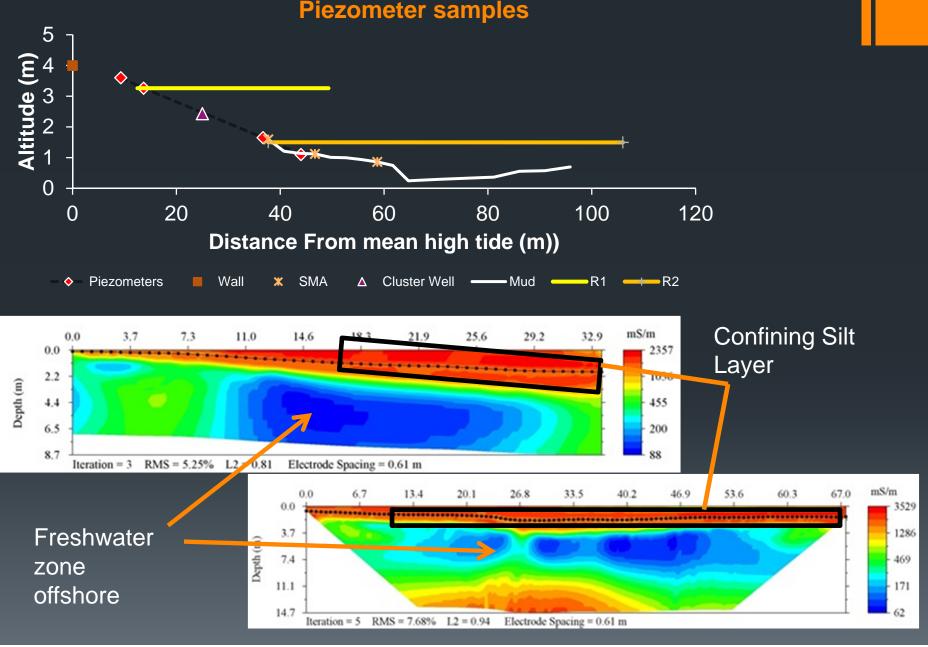
Unconsolidated Glacial Sands aquifer

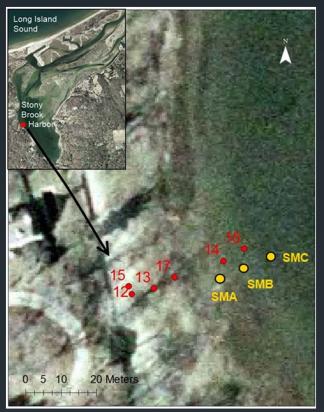
Terrestrial Gradient = 0.073, n = 0.66

- Methods:
- Resistivity Transects
- Piezometer sampling of porewater along cross shore transect
- Seepage meter measurements using Lee-type Meter



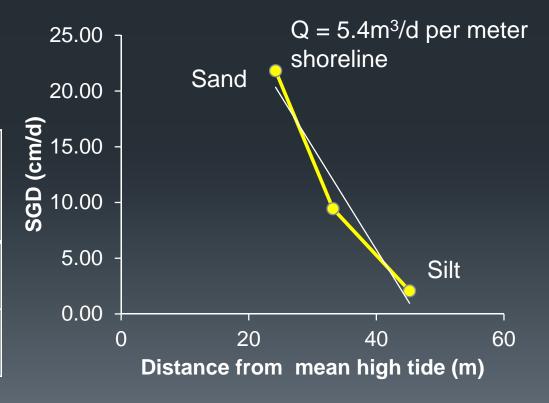




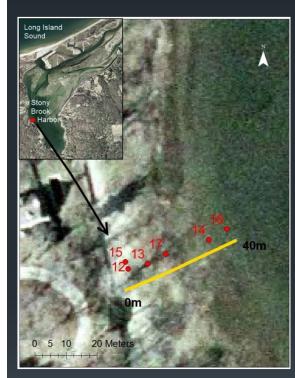


# Submarine Groundwater Discharge Rates

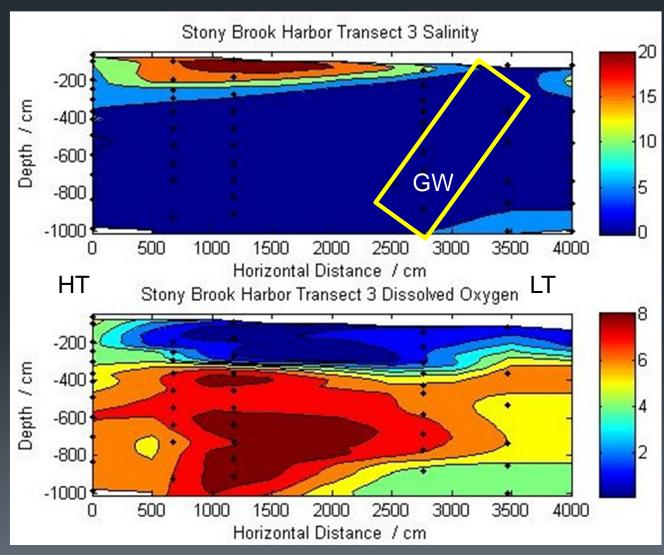
Layer	SGD Rate (cm/d)	Grain Size d(0.5) mm			
Med. Sand	21.8	0.61			
Coarse Silt	2.1	0.032			



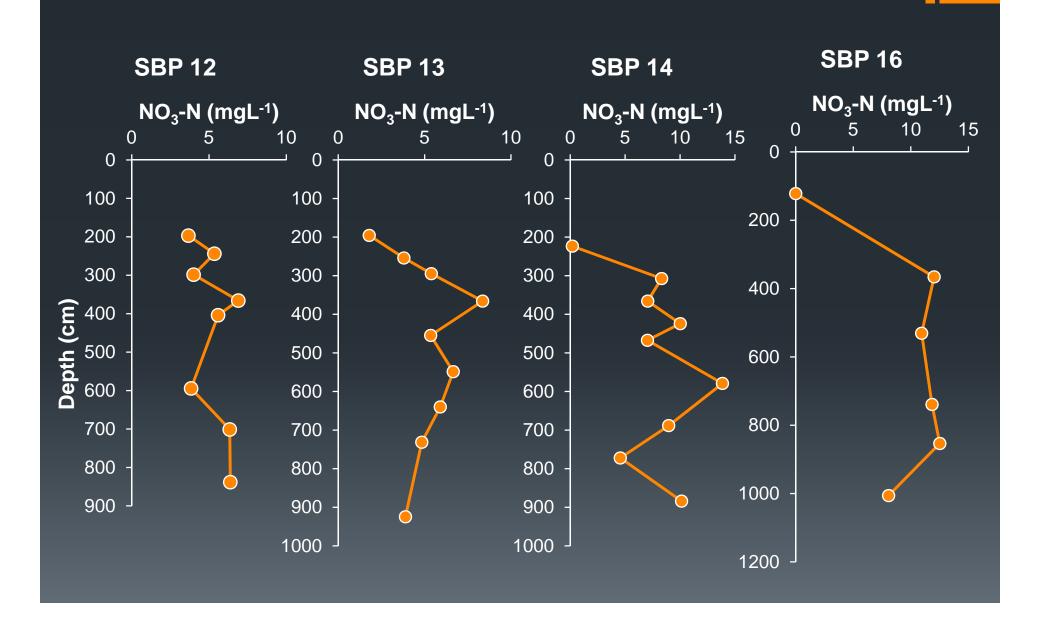
#### Salinity and Dissolved Oxygen in Porewater



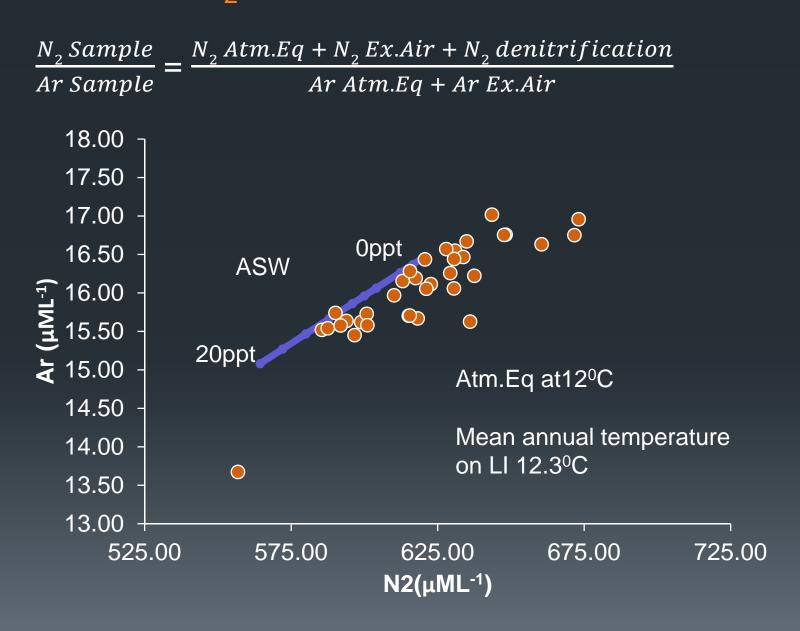
Average D.O (mg/L) Fresh Groundwater: 6.6 Brackish Porewater: 3.5 Overlying Water:7.7



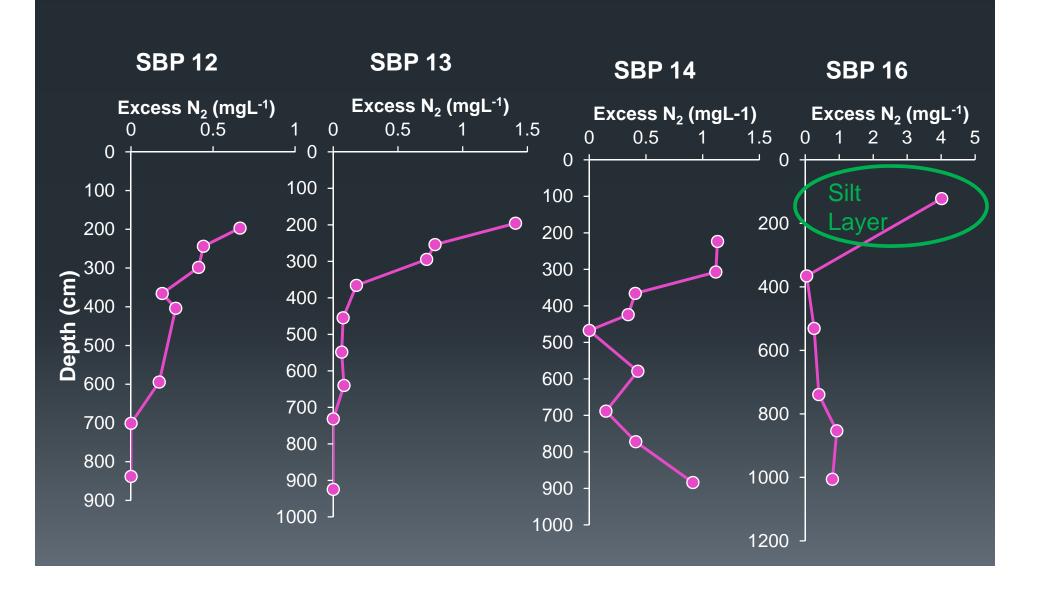
#### Nitrate Porewater Profiles



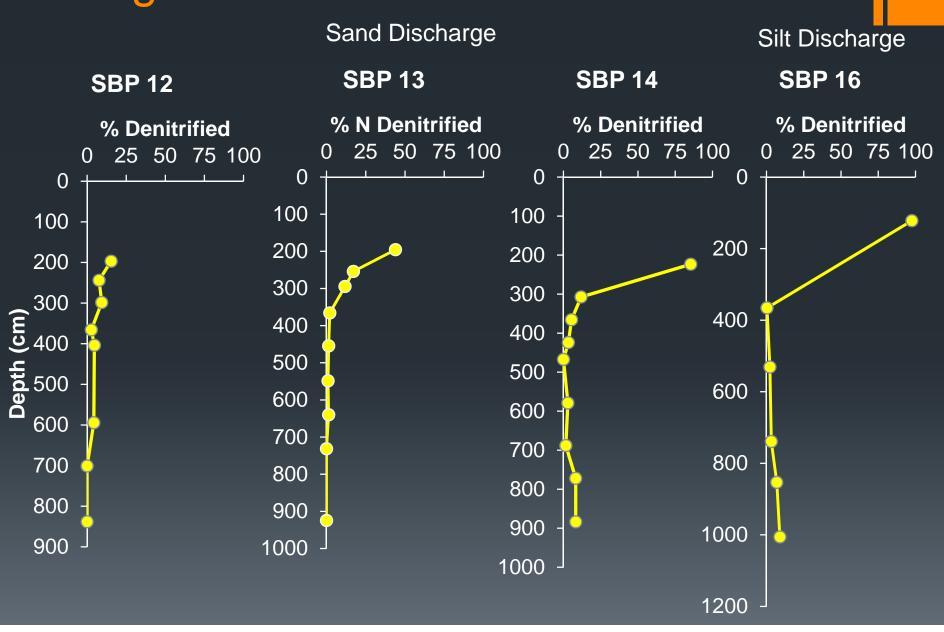
#### Dissolved N<sub>2</sub>/Ar to Determine Denitrification



# Excess N<sub>2</sub> Porewater Profiles

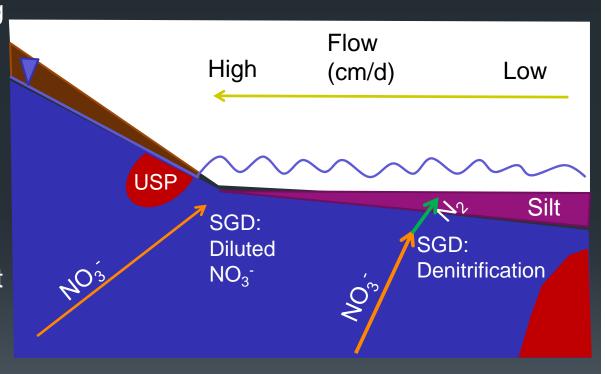


#### Nitrogen Loss Conclusions



- Terrestrial driven SGD can extend for tens of meters offshore
- Coarse silt typical of harbor bottoms acts as a confining unit
  - High DOC in silt layer drives denitrification
- Denitrification can be measured using dissolved N<sub>2</sub>/Ar method in mixed salinity pore water
- Where discharge is highest NO<sub>3</sub><sup>-</sup> attenuation is due to dilution
- Up to 60% of N loss in silt profiles is due to denitrification

# New Conceptual Model for Oxic-Oxic Discharge





# Nutrient Dynamics in a Subterranean Estuary over two Spring-Neap tidal cycles

# Caitlin Young, Josephine Durand, Amruta Rajendra and Gilbert N Hanson

Stony Brook University, Geosciences Department, Stony Brook, NY 11794 Correspondence: caitlin.young@stonybrook.edu



#### Abstract

Biogeochemical investigations of nutrient cycling during submarine groundwater discharge typically require days or weeks to complete. Resulting chemical profiles assume temporal stability of salinity and redox conditions in a subterranean estuary. Resulting nutrient load budgets are used in land management planning, which affects coastal systems on the decadal timescale. Therefore understanding temporal stability of subterranean estuary is critical for long term policy planning. Porewater samples (n = 262) were collected daily for 30 days to investigate the salinity and nutrient stability of a subterranean estuary during submarine groundwater discharge into an embayment of Long Island Sound, NY. Porewater was collected from a cluster well installed in an intertidal zone from intervals of 1m to a maximum depth of 9.1m. Results show temporal salinity and dissolved oxygen stability of both the upper saline plume and fresh groundwater zone. High terrestrial hydraulic gradient results in flow patterns that are stable despite daily 2 meter tidal oscillations. Nitrate distribution follows a redox gradient, where upper saline plume NO<sub>3</sub>-N averages  $0.2\pm0.25$ mgL<sup>-1</sup>, underlain by a fresh groundwater zone with average  $6.25\pm2.7$ mgL<sup>-1</sup>NO<sub>3</sub>-N at a depth of 9.1m. Inorganic phosphate concentrations are low. A salinity model of SGD flux reveals water table overheight during spring tide decreases freshwater discharge. Spring tide freshwater discharge is 0.39L min<sup>-1</sup> m<sup>-1</sup>, as compared to 2.0L min<sup>-1</sup> m<sup>-1</sup>during neap tide. Water table overheight causes ponding of freshwater during spring tide, which dilutes a nitrate plume and lowers average NO<sub>3</sub>-N concentrations in the 3.6-4.7m sampling depths. These results provide new insight to how spring tide aquifer overheight effects nutrient distribution in a subterranean estuary.

# Site Description

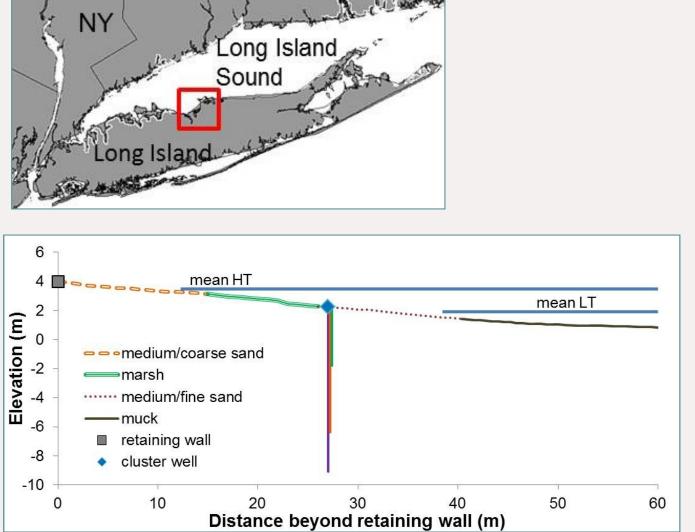


Figure 1. Location of Stony Brook Harbor (top) and subterranean estuary field area (right). Detailed cross section shows placement of cluster well, at the base of marsh in the intertidal zone. Mean high and low tides are shown for reference.



Stony Brook Harbor is an embayment located on the southern side of Long Island Sound in New York State (Suffolk County). The shallow harbor covers 4.5 sq. km with direct connection to Long Island Sound via a narrow, northeastern inlet adjacent to the mouth of West Meadow Creek. The deepest point in the inlet is approximately 10 m below Mean Sea Level. Figure 3 shows an overall snapshot of Stony Brook Harbor location. The average tidal range (measured between mean high and low water levels) for the period 1960 to 1978 was 6.6 feet at nearby Port Jefferson Harbor, which is a similar size and geometry to Stony Brook Harbor.

The shallow unconfined water table aquifer over most of Long Island is within the Upper Glacial aquifer unit. Groundwater movement generally perpendicular to water table contours. In general, water north of the regional groundwater divide, which trends east-west across the island, moves northward towards Long Island Sound, and water south of the divide flows southward toward the Atlantic Ocean. Horizontal hydraulic conductivity is estimated at 70.1md<sup>-1</sup>, with 10:1 horizontal to vertical anisotropy

#### Methods

#### Well Sampling

Three monitoring wells were installed as a cluster to enable easy sample collection; well location shown in figure 1 (W). Wells were screened at intervals of 0.9m with a screen length of 0.15m. Samples were collected from ten depths: 0.91, 1.8, 2.7, 3.6, 4.6, 5.5, 6.4, 7.3, 8.2, and 9.1 meters below grade. To allow sampling during high tide situation, polyethylene tubing (Grainger, I.D 0.64cm) was extended to a bulkhead, 10m up gradient of the high tide mark. Samples were collected daily between 9:30 am to 10:30am EST, 27 day period between 9/26/11 and 10/25/11.

At each sampling depth, 3 well volumes were pumped prior to sample collection. Field parameters of temperature, conductivity, salinity, dissolved oxygen and pH were measured using a YSI-556 handheld multi-probe meter with flow-through cell. For each parameter, the reported accuracies are: pH  $\pm$  0.2, temperature  $\pm$ 0.150 °C, and dissolved oxygen  $\pm 0.2$  mg/l and conductivity  $\pm 0.1\%$  (YSI instruments). To record tidal oscillation during the sampling period a pressure logger (Solinist #3001) was installed in an adjacent well.

Total NO<sub>3</sub>-N was determined by using Lachat Instruments FIA-6000 flow injection type automated analyzer. Concentrations are NO<sub>3</sub><sup>-</sup>+NO<sub>2</sub><sup>-</sup>, is expressed in mg/l of nitrogen. Reactive phosphate was analyzed using the spectrophotometric ascorbic acid method.

#### Silica Dissolution Experiment to determine pore water residence time

Residence time of porewater in the upper saline plume ( $\tau$ ) was determined using dissolved silica as a tracer to determine kinetics of quartz dissolution in seawater. Sediment samples were collected at the cluster well location from a depth of 10cm beneath the sediment surface. Overlying water was gathered from a point 12m offshore of mean low tide. Sediment was sorted to remove any grain size larger than 4mm diameter. Homogenized sediment and filtered seawater were placed in 50ml polypropylene vials at a water-rock ratio of 1.4. Vials were sealed and placed in a dark temperature bath at 11°C for the duration of the 38 day experiment. Every 1-3 days, a vial was removed and porewater was collected for silica analysis.

### Results-Salinity and Dissolved Oxygen, Nitrate, Phosphate concentrations from 0.91m to 9.1m depth sampling

• 0.91<sub>m</sub> • 1.8<sub>m</sub> • 2.7<sub>m</sub> • 3.6<sub>m</sub> • 9.1 ----tide —spring-neap high

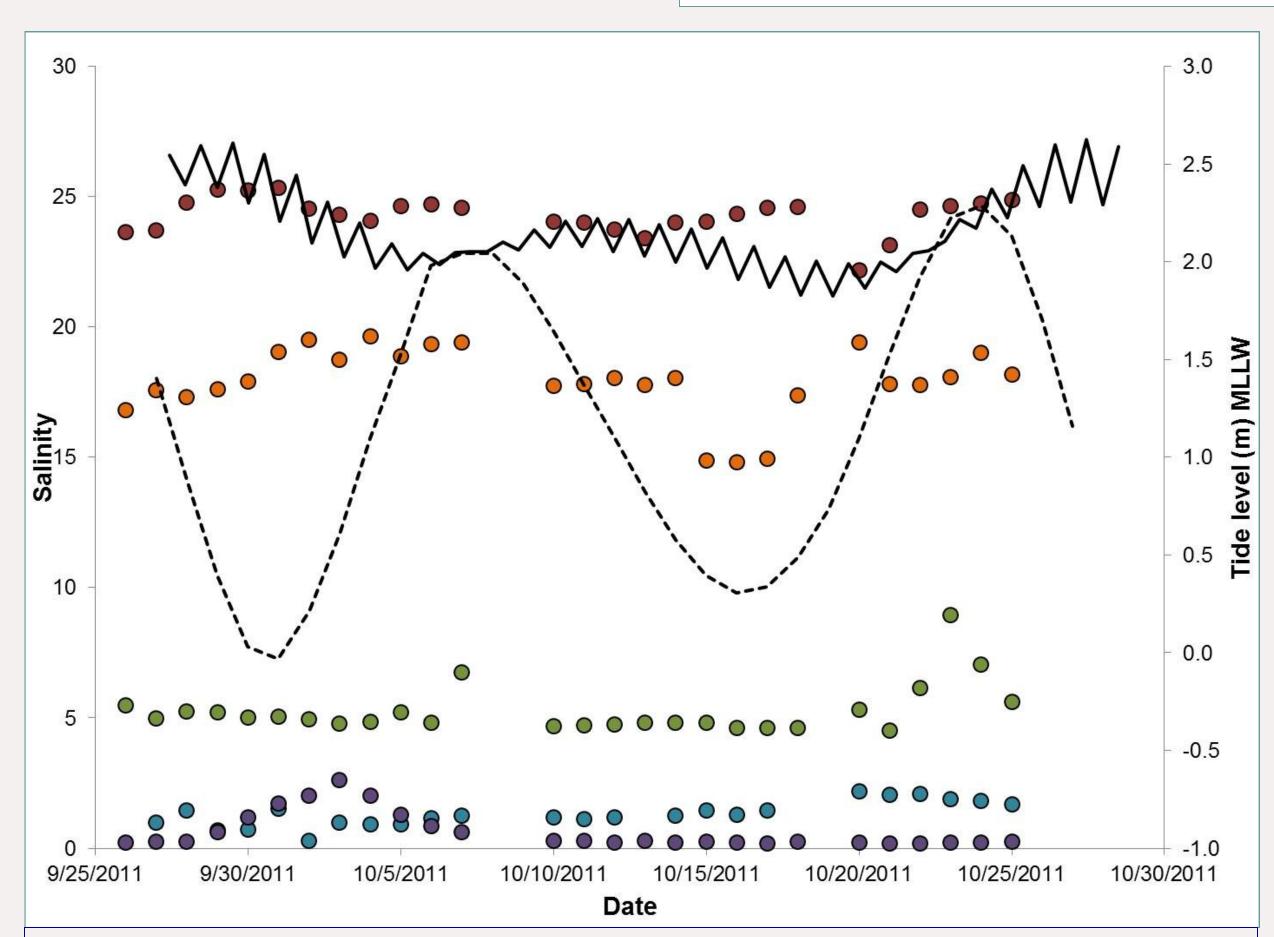
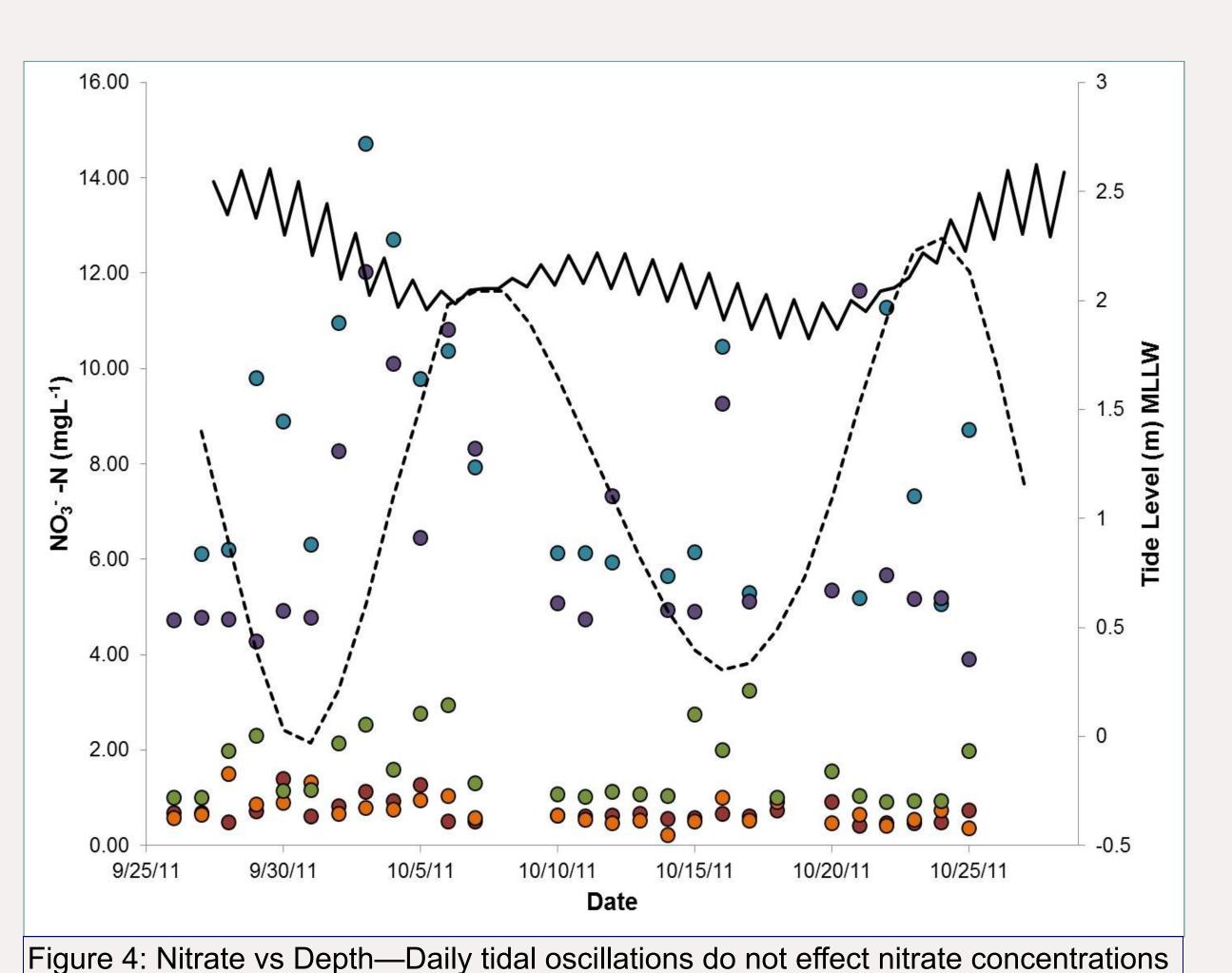


Figure 2: Salinity vs Depth. Salinity of Stony Brook Harbor overlying water averages 26.5ppt, which is higher than average salinity of 24.3 taken from a depth of 0.91m below the sediment surface. Salinity decreases to an average of 5.27at a depth of 2.7m delineating the lower boundary of salt penetration. Salinity does not vary with springneap cycling.



in the STE due to low concentrations in the upper saline plume. Instead variations in spring-neap tidal cycle are observed in porewater from depths 3.6-9.1m. Peak values are seen during late neap tide, 10-5-11 to 10-8-11, following minimum values observed during spring high tide 9-28-11. High nitrate concentrations throughout the freshwater portion of the STE indicate the presence of a plume, possibly from an up gradient golf course.

#### Table 1: Summary of results showing average and S.D for each sampling depth

Depth (	(m)	0.91	1.8	2.7	3.6	4.6	5.5	6.4	7.3	8.2	9.1
Salinity	v (27)	24.3 ± 0.7	17.9 ± 1.3	5.27 ± 0.9	1.32 ± 0.5	1.42 ± 0.6	0.94 ± 0.4	0.76 ± 0.6	0.56 ± 0.3	0.5 0.5	± 0.8 ± 1.1
dissolve (mgL <sup>-1</sup> )	ed oxygen (27)	1.01 ± 0.3	0.86 ± 0.3	1.3 ± 1.1	7.1 ± 0.9	7.5 ± 0.5	7.5 ± 0.5	7.8 ± 0.7	7.9 ± 0.5	7.7 0.8	± 7.7 ± 1.5
NO <sub>3</sub> -N	(27)	0.7 ± 0.2	0.7 ± 0.3	1.6 ± 0.7	8.21 ± 2.7	8.5 ± 3.8	7.9 ± 3.2	6.1 ± 2.2	6.3 ± 2.3	6.2 2.5	± 6.2 ± 2.7
PO <sub>4</sub> <sup>+2</sup> -I	P (23)	$\begin{array}{c} 0.08 \ \pm \\ 0.04 \end{array}$	0.13 ± 0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

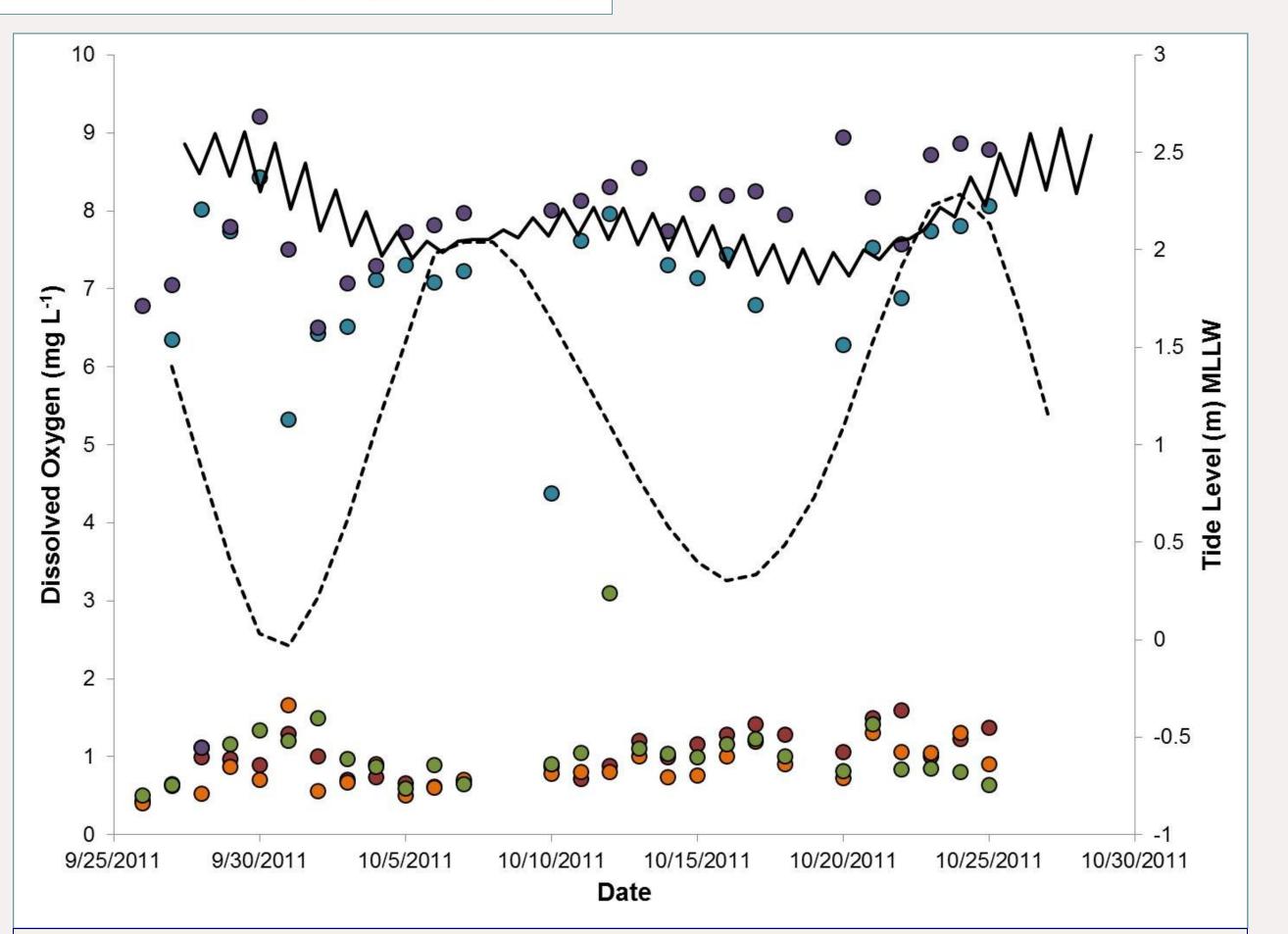
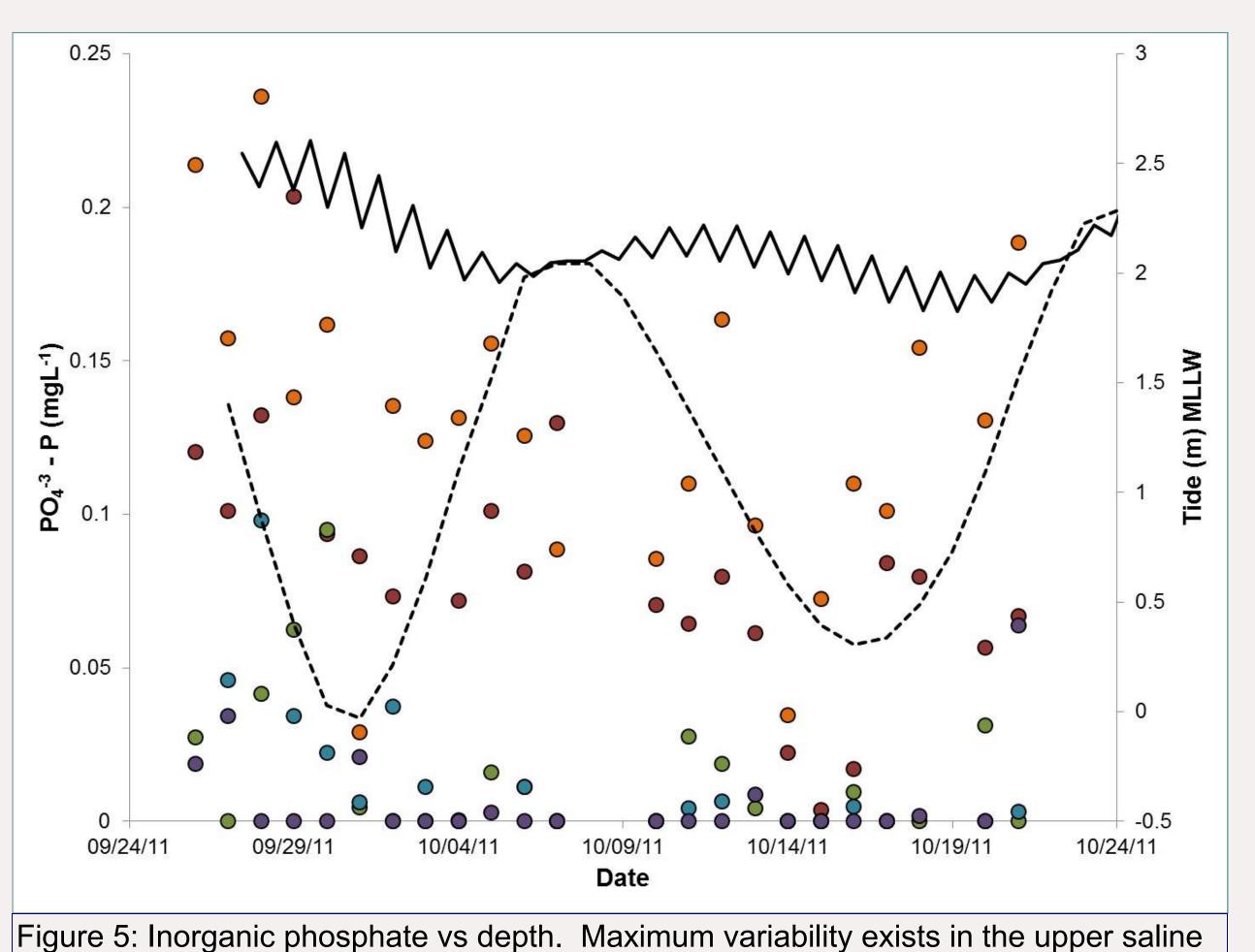
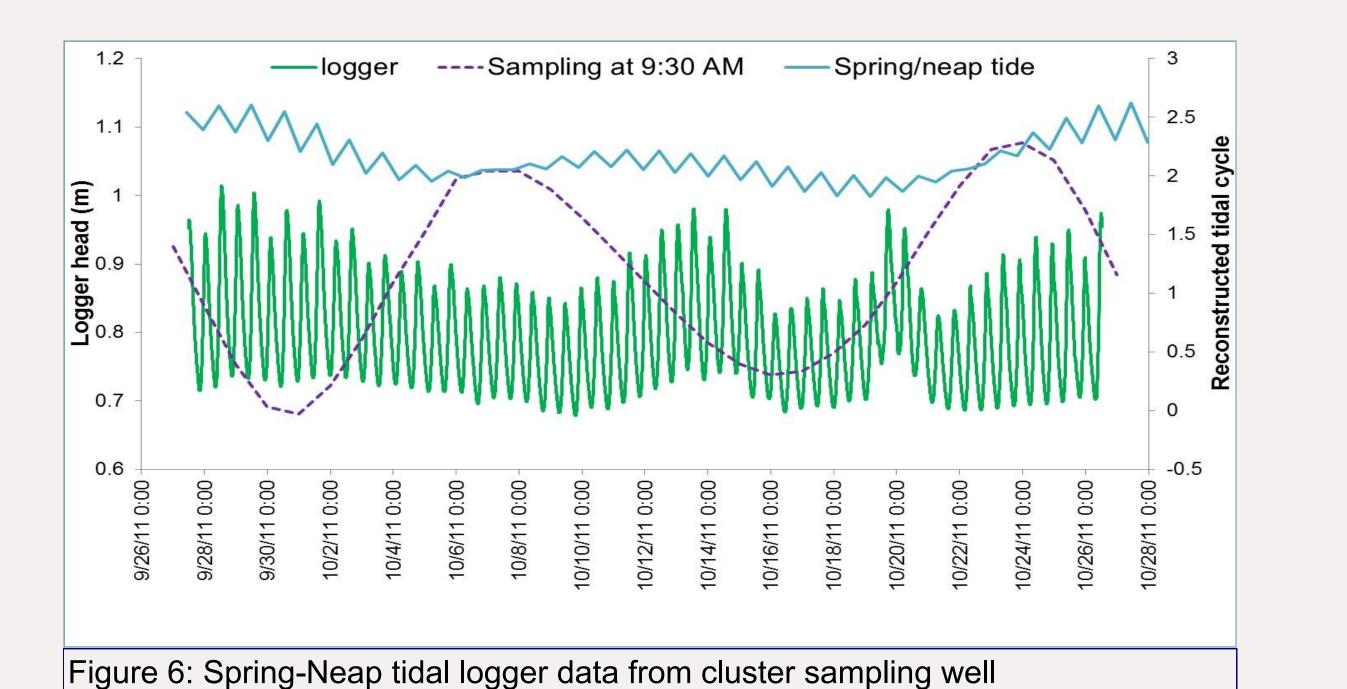


Figure 3- Dissolved oxygen (DO) vs Depth - DO exhibits minimal variation in the upper saline plume during 27 day sampling period. At sampling depth 0.91m DO averages 1.01±0.3mgL<sup>-1</sup> then decreases to 0.86±0.3mgL<sup>-1</sup> at a depth of Freshwater concentrations at depths 3.6-9.1m average 7.6±0.8mgL<sup>-1</sup>

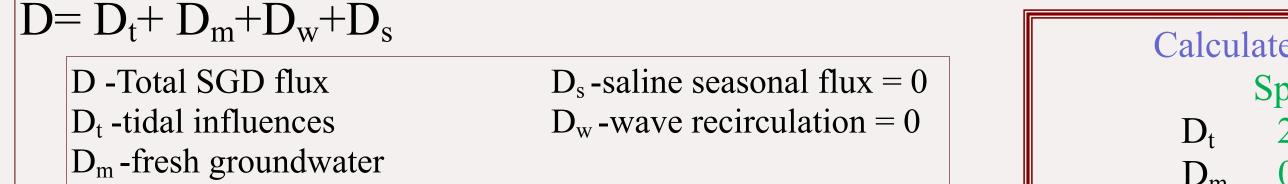


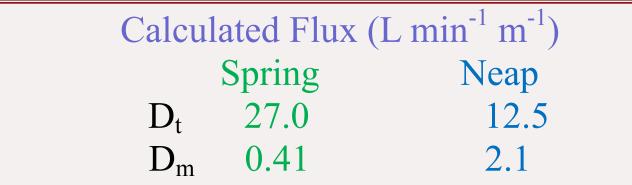
plume, where concentrations average 0.08±0.04mgL<sup>-1</sup> and 0.13±0.05mgL<sup>-1</sup> for sampling depths 0.91 and 1.8 respectively. At sampling depths greater than 1.8 m, inorganic phosphate concentrations average 0.02mgL<sup>-1</sup> or less, at the limit of analytical uncertain-



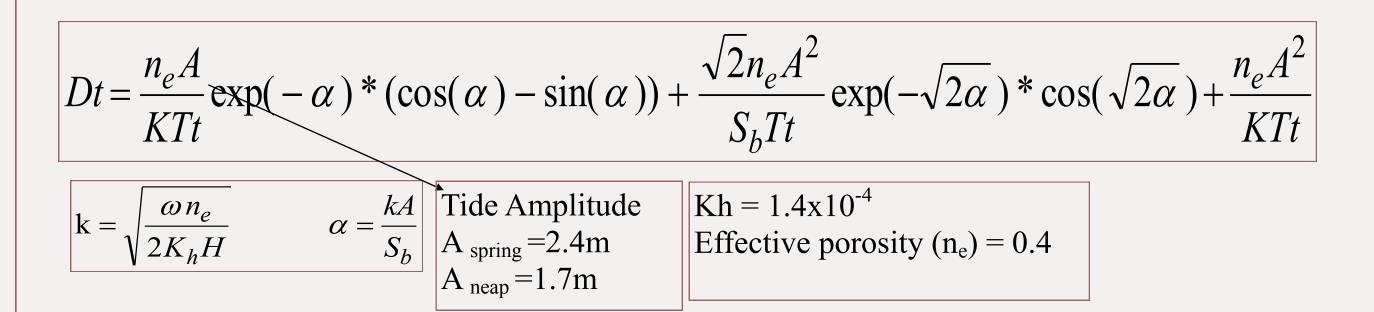
Discussion—Calculation of SGD Flux for Spring and Neap Tides

#### Flux Calculations using a salt balance model

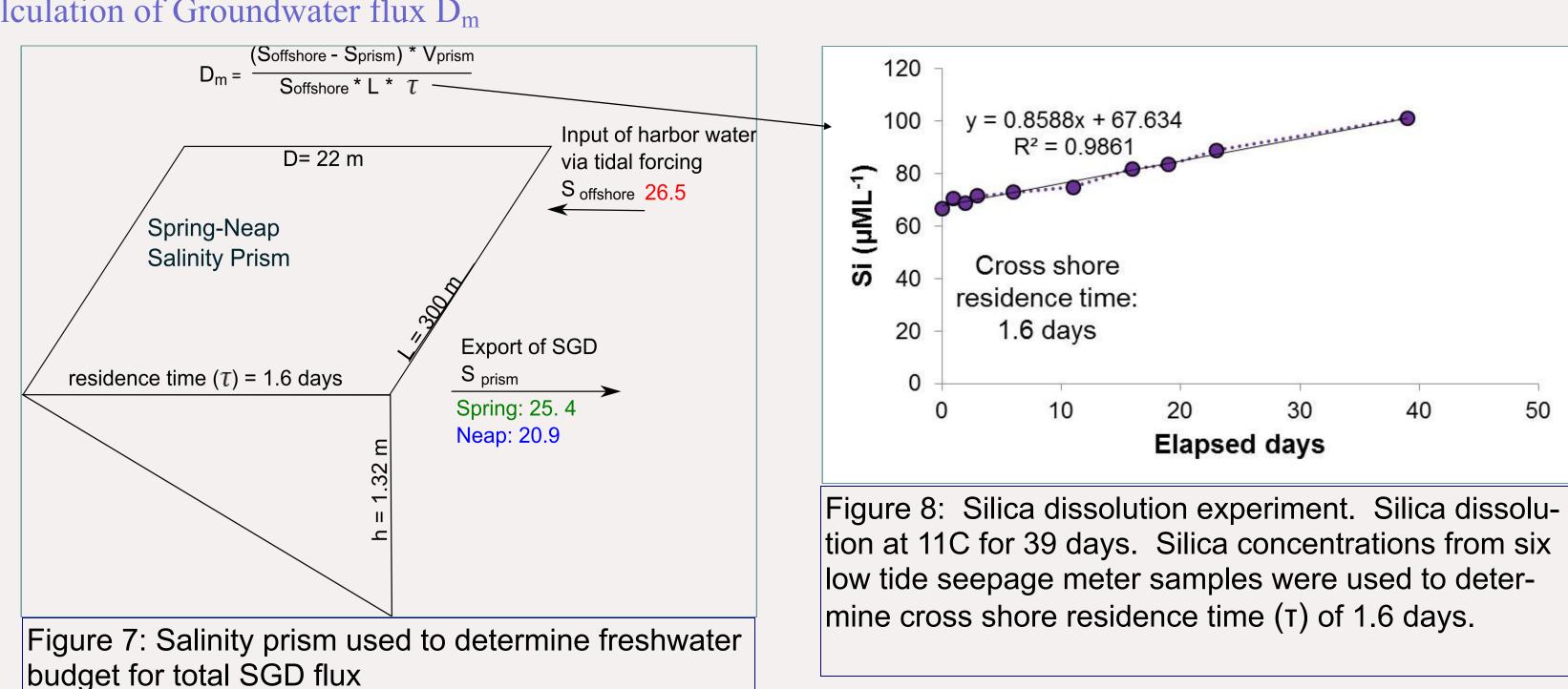




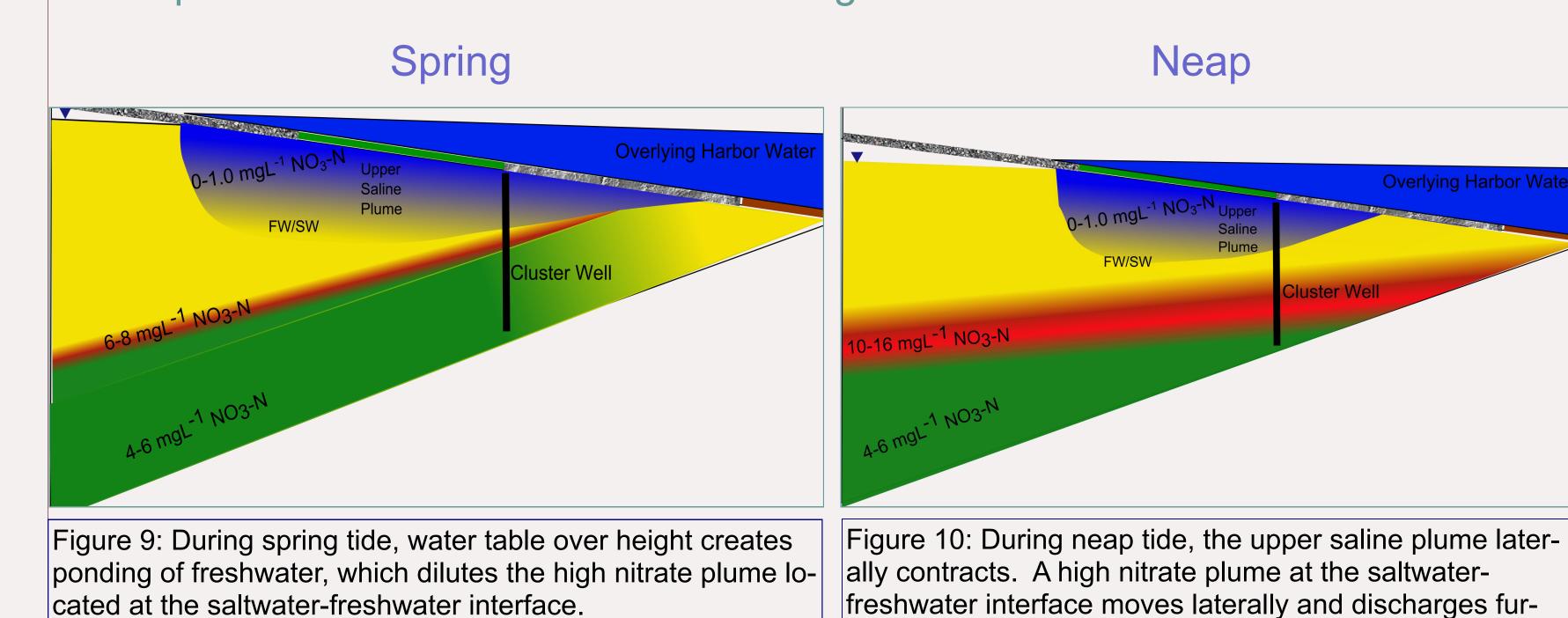
#### Calculation of Tide driven flux D<sub>t</sub>



#### Calculation of Groundwater flux D<sub>m</sub>



#### Conceptual Model of Water Table Overheight Affect on Nitrate Concentrations



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JENG, D. S., MAO, X., ENOT, P., BARRY, D. A. & LI, L. 2005. Spring-neap tide-induced beach water table fluctuations in a sloping coastal aquifer. Water Resources Research, 41.

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ROBINSON, C., GIBBES, B., CAREY, H. & LI, L. 2007. Salt-freshwater dynamics in a subterranean estuary over a spring-neap tidal cycle. Journal of Geophysical Research-Oceans, 112.

# H53D—1551 Submarine groundwater discharge (SGD) in Stony Brook Harbor, NY



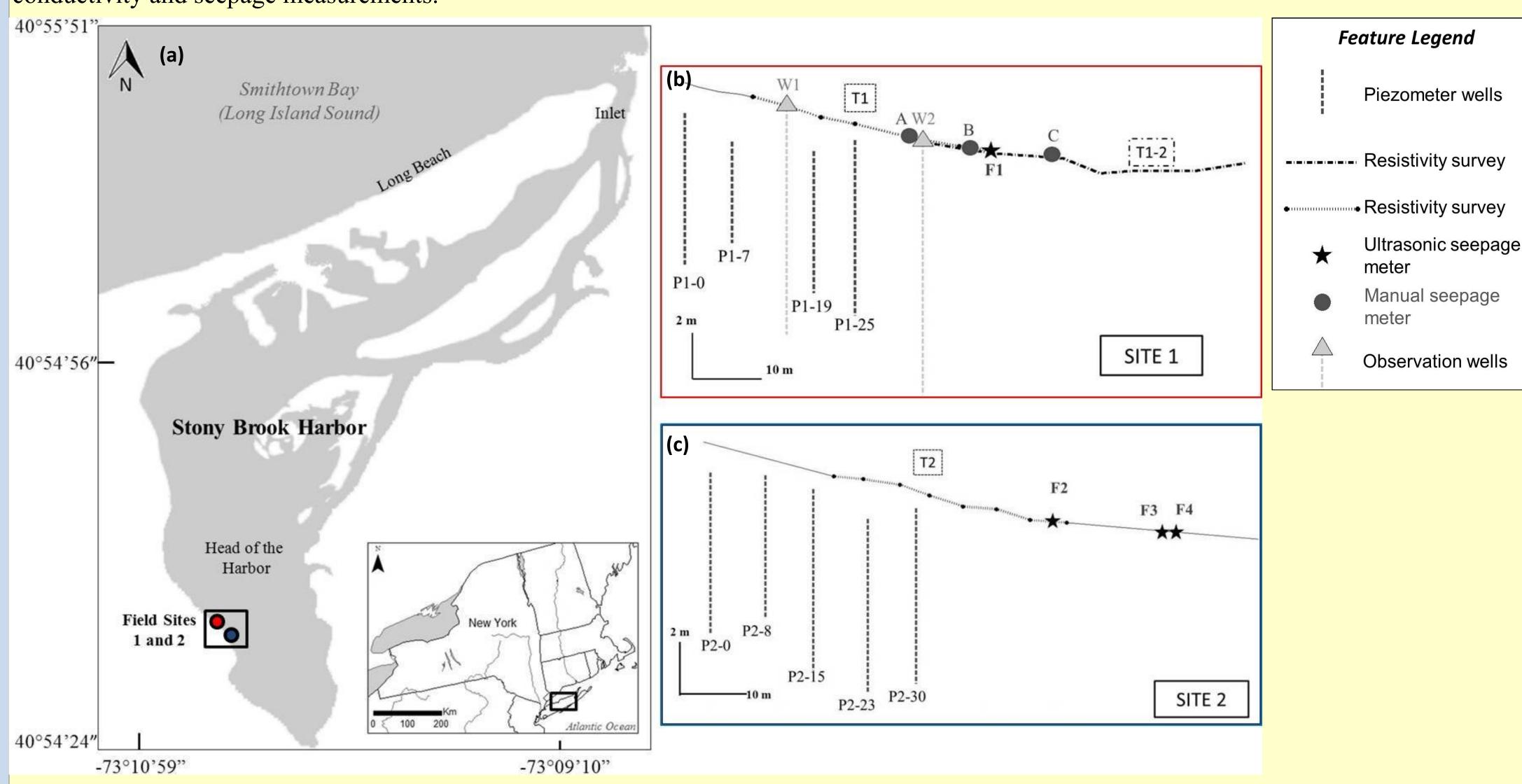
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## 1. Objective

As nutrients can significantly impact coastal ecosystems, understanding their path to embayments and oceans is crucial. In Stony Brook Harbor (Long Island, NY), submarine groundwater discharge (SGD) is the only significant contribution of freshwater and thus constitutes the main pathway for nutrients, which may eventually reach Long Island Sound. Subterranean estuaries have been shown to be highly reactive zones where nitrogen attenuation can occur. Quantifying denitrification at the harbor scale requires first to estimate the fluxes and volumes of water involved in SGD. The purpose of this study was to characterize the hydrogeological framework and SGD distribution of Stony Brook Harbor through an integrated approach using various geophysical techniques. Electrical resistivity surveys were combined with water sampling in piezometers, point conductivity and seepage measurements.



(a) Site map of Stony Brook Harbor and inclusion showing the locations of the two field sites. Sketch maps of relative positions of the different measurements at site 1 (b) and site 2 (c). The sketches are presented with 5x vertical exaggeration.

### 2. Methods / Equipment

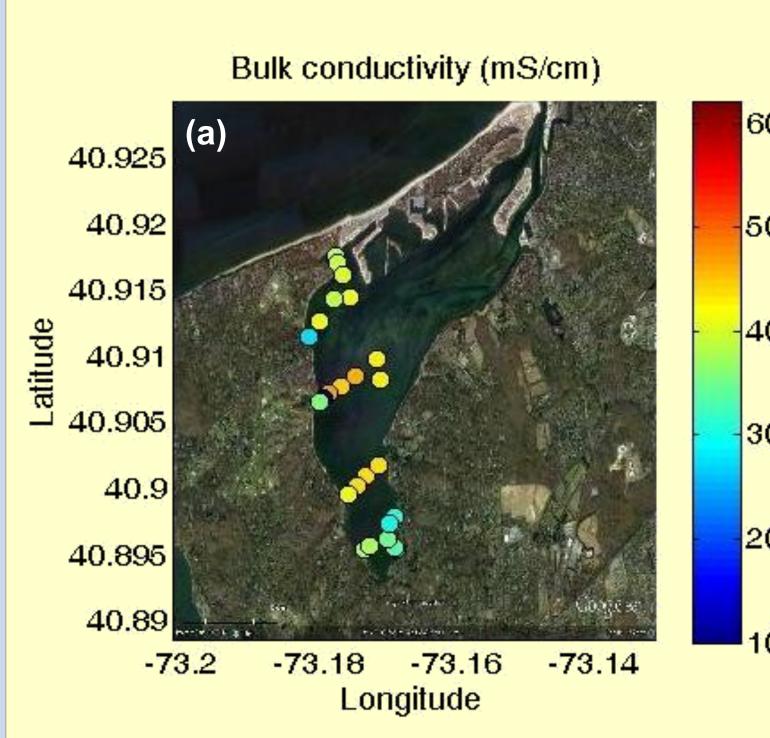
Trident probe: measures bulk conductivity and temperature at 60 cm depth, as wells as the conductivity and temperature of overlying seawater. Acquisition between 3/28/11 and 4/11/2011.

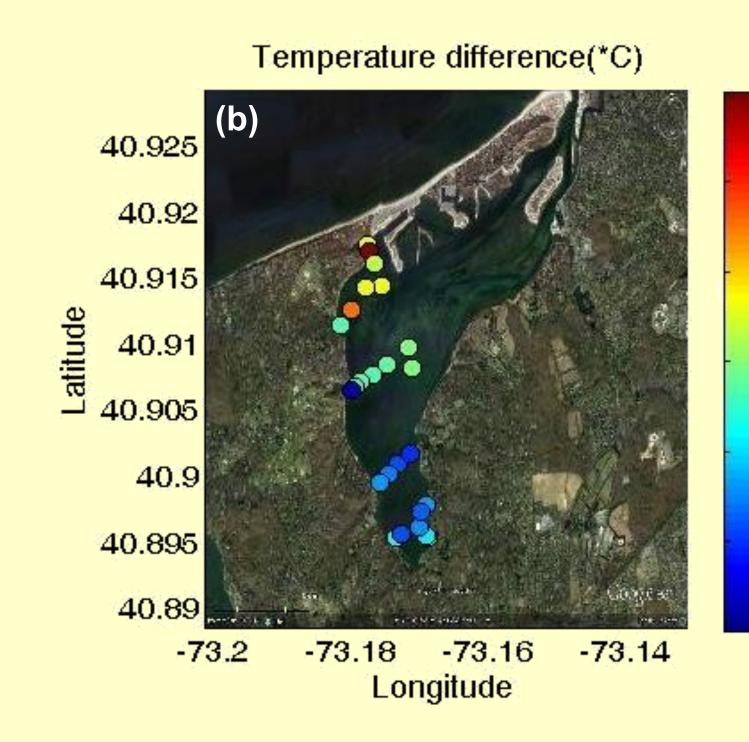
Electrical resistivity surveys: SuperSting 8 channel receiver and Earth Imager 2D interpretation software. Spatial resolution of 60 cm. Acquisition between 4/27/11 and 5/31/11. At site1, two transects distant of 6 m were acquired perpendicular to the shore line. Another transect was acquired parallel to the shore line at the same location. Each section is 34 m wide and 8 m deep. The combination of three sections creates a pseudo 3D image of the groundwater distribution. At site 2, about 70 m South of site 1, only one survey was performed, perpendicular to the shore line. • Ultrasonic seepage meter. Sampling frequency: 15 minutes. Acquisition from 7/22/11 to 7/26/11.

Manual seepage meter (Lee type). Acquisition on 8/14/2012 from 10 AM to 7PM. The water collected from the bags was analyzed using a YSI 556 probe to measure conductivity, temperature and salinity.

# 3. Results

### Conductivity and temperature from the Trident data





Trident probe transects across Stony Brook Harbor. (a) Bulk conductivity at 60 cm depth, in mS/cm. (b) Temperature difference between the sediments and the overlying seawater, in °C.

• The Harbor exhibits a relatively homogeneous behavior at a big scale. The bulk resistivity values are high, which indicates that top of the sediments are saturated with seawater. There is no significant contrast in temperature between the sediments and the overlying seawater.

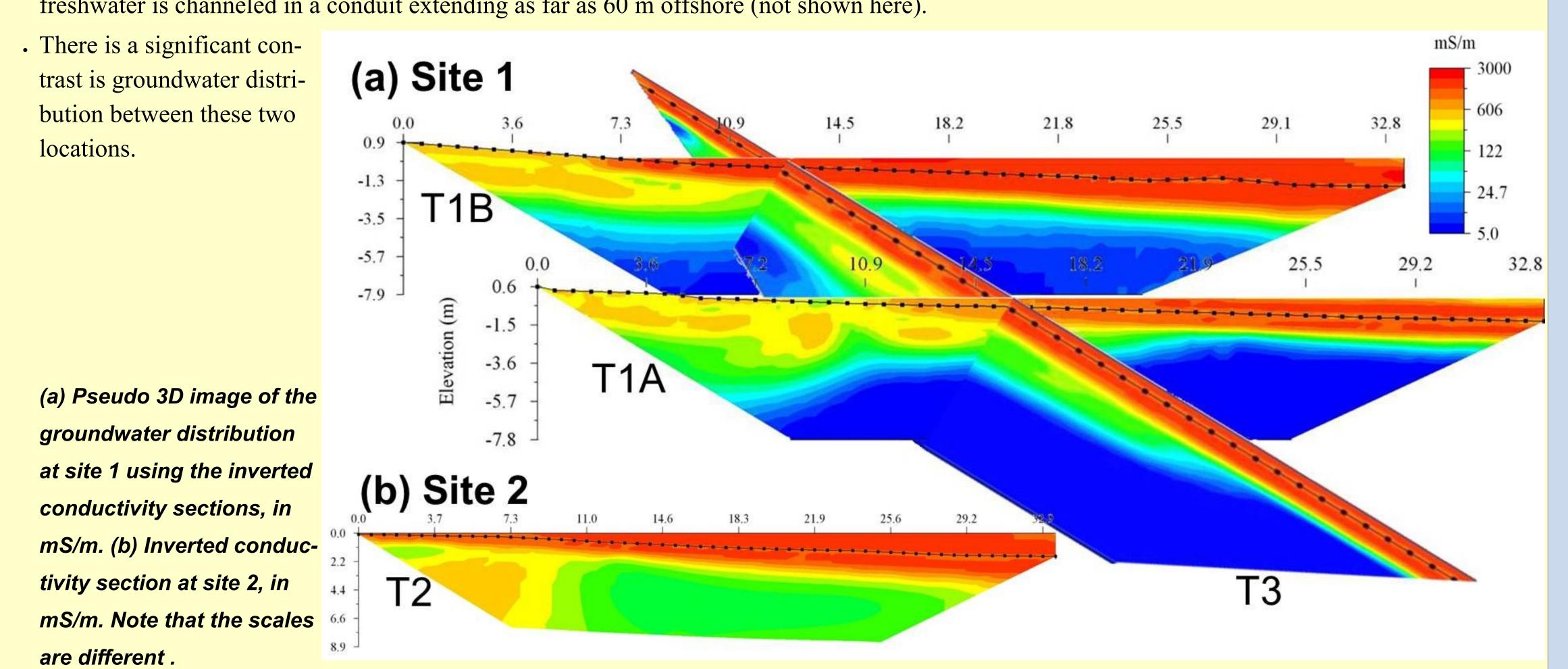
Several electrical resistivity surveys were performed all around the harbor and gave similar results. More focus was brought to the sites 1 and 2. It was then observed that the apparent homogeneity of the conductivity near the surface contrasts with the local heterogeneities revealed by the more detailed resistivity measurements at these two locations.

### 3. Results (Continued)

#### Pseudo 3D imaging using electrical resistivity surveys

• On transect T2, the conductivity values are intermediate in most of the section. Values slightly smaller than the one of seawater are visible in the intertidal zone, between 0 and 11 m and down to 8m depth. This indicates a strong mixing zone between freshwater and seawater in the intertidal portion of the section and a more diffuse mixing farther offshore and at depth.

• At site 1, the three transects display a remarkable consistency in the features observed. Beyond 10 m, a superficial layer with very high conductivity is visible on all 3 profiles between 0 and 2 m depth. This suggests that the sediments are saturated with saline water and/or contain clay particles. Closer to the shore, on T1A and T1B, high conductivity values are observed between 0 and 14 m and down to 5 m depth, indicating a shallow zone of mixing in the intertidal zone. Below 6 m depth and farther offshore, very low conductivity values show that the mixing is localized, and that the freshwater is channeled in a conduit extending as far as 60 m offshore (not shown here).



# (a) <sub>0-</sub> P1-<u>0</u> Site 2 **(b)** P2-0 Horizontal distance from the first piezometer (m)

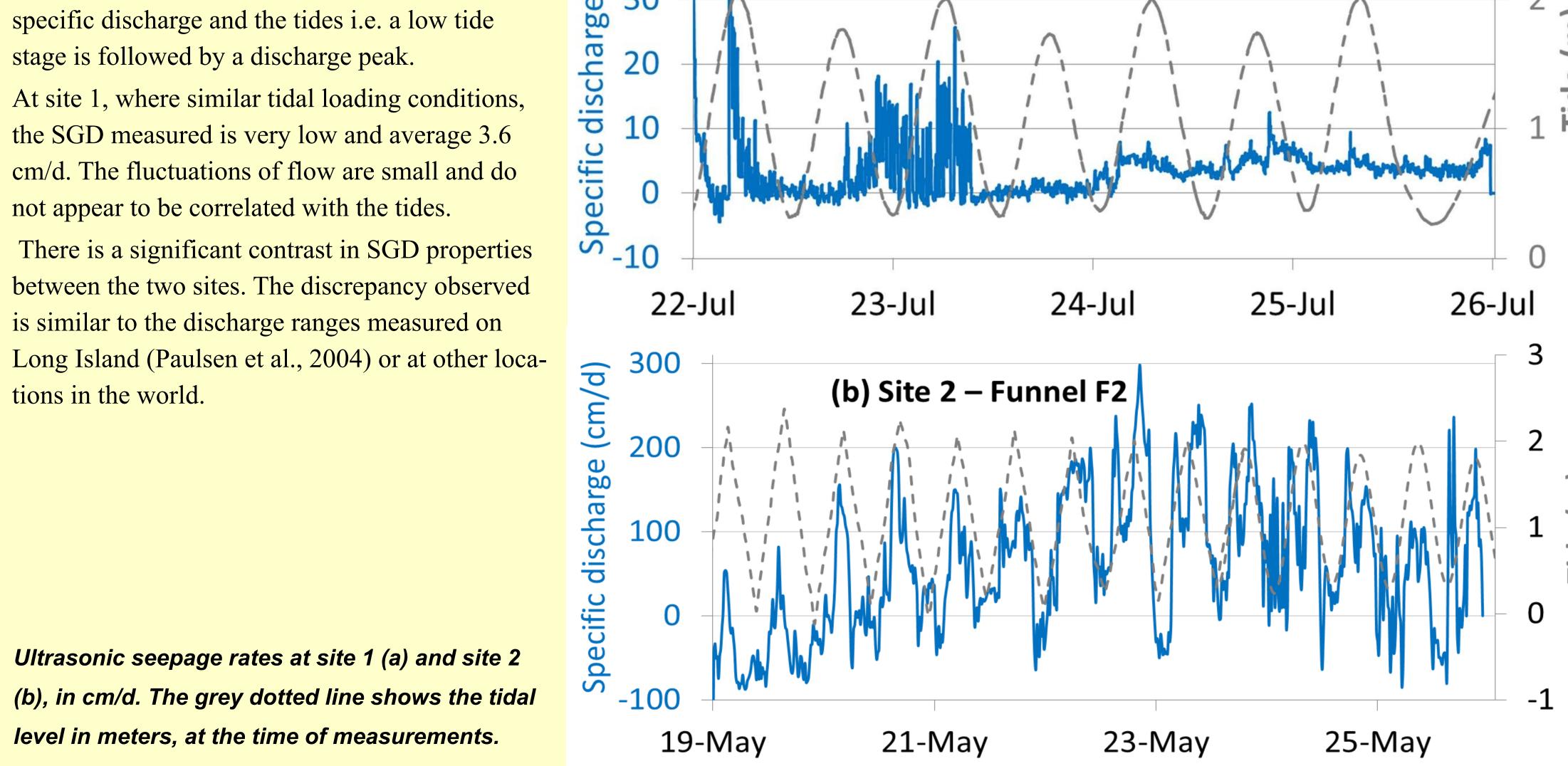
## Salinity (g/L) Salinity profiles using piezometer data • The piezometers P2-0 and P2-8 at site 2 present very low salinity under 2 m depth. The other wells have salinities above 10 g/L revealing diffuse mixing beyond the intertidal zone. The maximum values are found between 0 and 4 m depth in the intertidal zone, wells P2-8 and P2-15, showing strong mixing.

. At site 1, the intermediate salinity values are limited to the intertidal zone down to 5 m depth. Beyond this zone, very low salinity values are found. This suggests a localized superficial mixing zone, overlying a freshwater conduit, extending offshore and down to 10 m depth.

Salinity measurements in the piezometer wells at site 1 (a) and site 2 (b), in g/L. The black dotted rectangles represent the areas where piezometer and resistivity data overlap.

### Ultrasonic seepage measurements

- SGD rates measured at site 2 are high, with an average of 61 cm/d. The values range from –100 to 300 cm/d. There is a clear correlation between the specific discharge and the tides i.e. a low tide stage is followed by a discharge peak.
- . At site 1, where similar tidal loading conditions, the SGD measured is very low and average 3.6 cm/d. The fluctuations of flow are small and do not appear to be correlated with the tides.
- There is a significant contrast in SGD properties between the two sites. The discrepancy observed is similar to the discharge ranges measured on Long Island (Paulsen et al., 2004) or at other locations in the world.

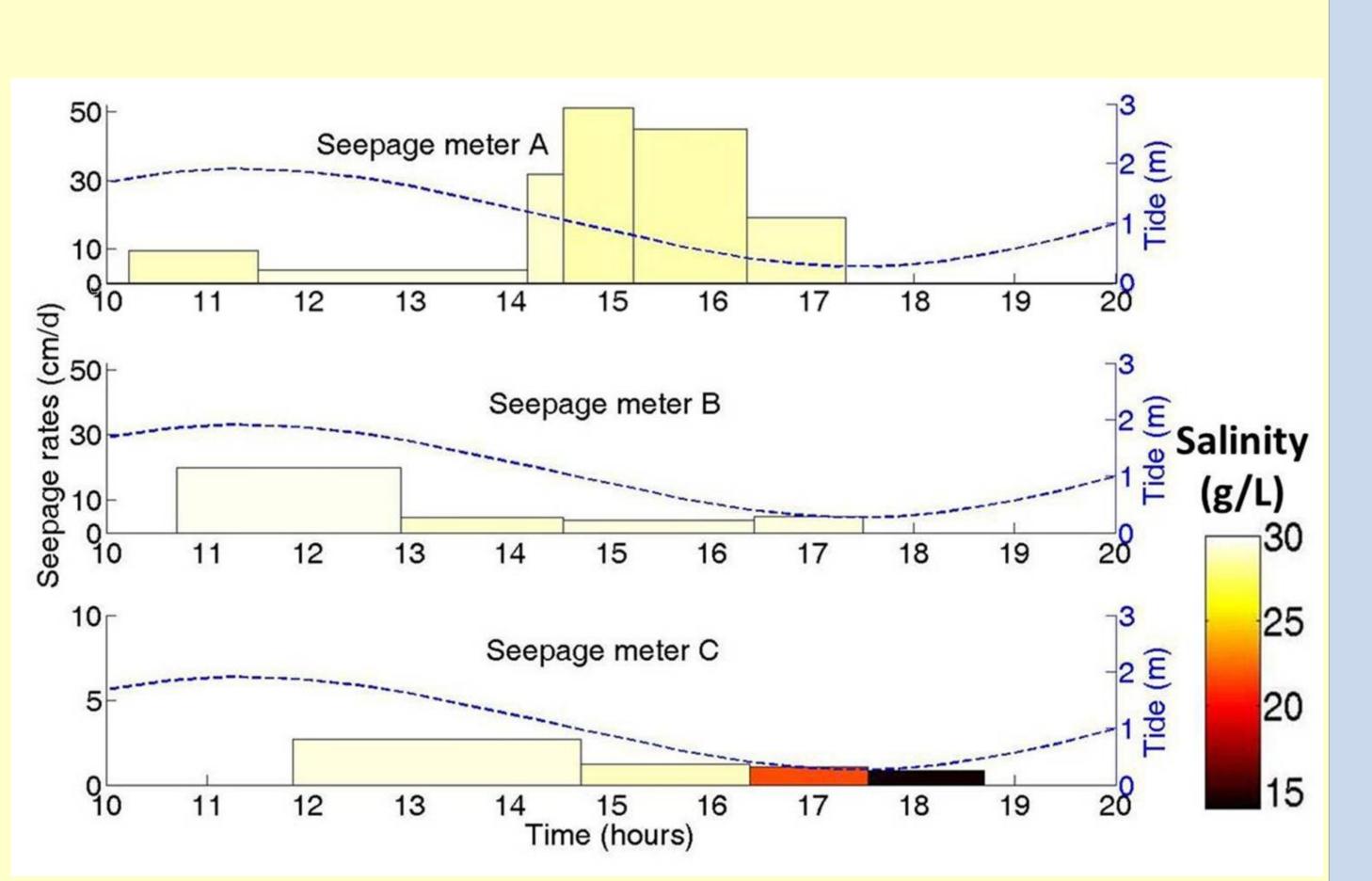


(a) Site 1 - Funnel F1

### 3. Results (Continued)

#### Lee type manual seepage meter

- . The manual seepage meter B was the closest to the ultrasonic seepage meter F1. The flow rates measured are similar: < 5 cm/d. There is no apparent correlation with the tide.
- The seepage meter A was close to the intertidal zone. SGD rates are more important: 23 cm/d and seem to be correlated with the tides.
- . The seepage meter C was located 30 m offshore and has the lowest SGD values < 3 cm/d. No correlation with the tides is observed.
- . The salinity values from the water seeping in A and B remains as high as the one of seawater during the whole sampling time. For C, however, a freshening is observed at low tide, revealing the presence of freshwater. This agrees with the previous observation of a conduit extending
- . The seepage meter A was located in a sandy zone, whereas B and C were in a muddy superficial layer, which thickness increases away from the shore.



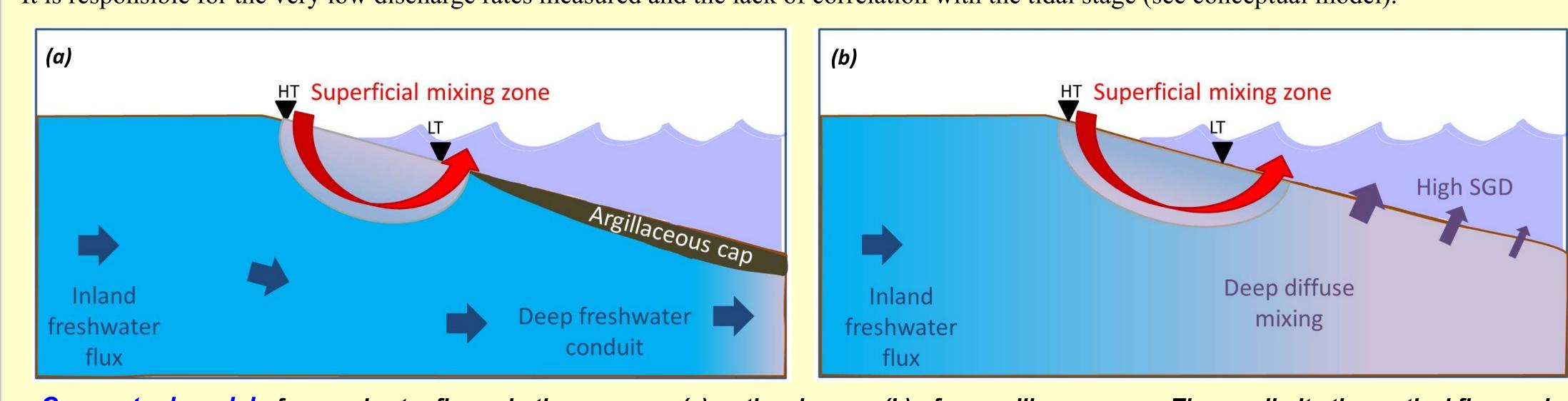
Results of salinity and flow rates measurements using the manual seepage meters. The meters A, B and C were placed at 1, 10 and 22 m of the low tide mark respectively. Each square represents a sampling bag, the base the sampling duration and the color the salinity value. The blue dotted line shows the tidal level. Note the different scale for the seepage meter C.

### 3. Conceptual model and discussion

• Two drastically different hydraulic properties of SGD were observed in Stony Brook Harbor, NY. At one site, we observe a superficial mixing zone in the intertidal zone and diffuse mixing at depth and farther offshore. The SGD there is high and correlated with the tides. At the other site, the only mixing observed is localized to the intertidal zone. Below that, the freshwater is channeled in a conduit and moves offshore. SGD rates measured there are very low and do not appear to be correlated with the tides. All methods of observation agree remarkably well.

We hypothesize that the difference between these two sites is due to the presence of a layer with specific hydraulic properties that controls the flow. This layer of vey low hydraulic conductivity inhibits the mixing between the fresh and overlying seawater. This results in the creation of a conduit that channels the freshwater from land to great distance offshore.

The main difference between these two locations relies on the presence of a muck layer, which thickness reaches 85 cm at 30 m from the shore. This layer, is rich in clay and saturated with seawater. This argillaceous layer acts as a cap by providing a hydrological insolation to the freshwater. It is responsible for the very low discharge rates measured and the lack of correlation with the tidal stage (see conceptual model).



Conceptual model of groundwater fluxes in the presence (a) or the absence (b) of an argillaceous cap. The cap limits the vertical flow and thus controls the extent of infiltration, mixing and recirculation of the seawater.

The similarity of other resistivity surveys with the site 1 leads us to think that the layer extends throughout the head of the harbor. This agrees with other previous studies of sediment grain-size distribution that localized the very-fine particles in the low energy part of the harbor (Robbins, 1977). These findings are of real importance for nitrogen fluxes and balance at the scale of the harbor. The extent of the clay-rich layer is controlling the volume and location of the freshwater seeps. To be accurate and representative, the extrapolation of nitrogen concentration measurements should take the extent of the layer into account. Nitrogen analyses have also revealed significant differences in nitrates concentrations between these two locations, showing the crucial influence of the hydrogeological framework in the chemical reactions and species distribution (Young et al., H53D -

# 4. References

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